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EDITORIAL

TREATMENT OF FRACTURES

ATTENTION to the satisfactory treatment of fractures has become an absolute necessity to the majority of medical men, both on account of the great increase in these traumatic lesions and the progressive betterment of results obtained by leaders devoting much time to the subject.

The use of forces supplied by traction and countertraction, followed by fixation, is as old as the treatment of fractures itself. The modern trend of treatment adopts an increasingly greater proportion of mechanistic control of these ancient principles, yet the elementary factors remain as always. They may, however, be lost sight of in the maze of new mechanical aids and bold surgical procedures offered so bewilderingly to the doctor.

For the purpose of clarifying the situation, this symposium on fractures has been written by men selected on the basis of their geographic distribution as well as their knowledge of the various topics allotted. The reader may consequently feel that the ideas of treatment here exposed are national in breadth. Each author has put himself on a judicial plane in his writing, backed by the observations of his own experience. The doctor is encouraged to give to his patients with broken bones sustained interest and intelligent attention, while employing wholesome elementary principles of fracture treatment. At the risk of triteness, may I quote the slogan, "It is not the splint, but the doctor behind the splint that counts in the treatment of fractures."

To the list of distinguished contributors, my thanks for their coöperation in this time-consuming work. Their real thanks will come from the reader who digests the truths expressed and applies them in his daily practice.

Kellogg Speed, M.D.

FRACTURES

SINCE the dawn of time, fractures of the human skeleton have been a part of man's existence, but with the changing times one notes that the predominance of certain fractures changes. Thus in ancient Egypt, the most common sites of fracture appear to have been the cranium and the forearm; both these structures no doubt received blows from the *Naboot*, which were aimed at the skull and sometimes fended off by the arm. Fractures of the femur were then more numerous than they are today, but no fractures of the patella are recorded, perhaps because people went barefoot and had no slippery pavements upon which to fall. Today, however, the use of the automobile and the participation of large numbers of people in certain sports have made some types of fractures so common that they excite little comment. Nevertheless, our machine age, the labor and compensation laws, the new mechanical devices for the treatment of fractures have made the fracture problem a more complicated one. That it is serious for the surgeon as well as for the patient is clearly indicated by the fact that within the past two decades damage suits in fracture cases have greatly increased in number; as one surgeon has said, such suits seem always to lurk around the corner.

It is true of fractures, as of obstetrics, that the majority of physicians must assume responsibility in these cases, although only a minority are qualified to do the work well. Not only to the specialists in the large centers do these cases fall, but also to the doctors of the smallest towns and hamlets. As Dr. Speed has stated, such traumatic lesions are far more frequent now than formerly, and the results of treatment in the hands of experts has markedly improved. Yet since the victims of accidents cannot always be seen immediately by such experts, it behooves all members of the medical fraternity to know the principles upon which adequate treatment is based and to be familiar with as many of the finer points of therapy as can be utilized in their work.

These are the factors which determined us to bring out this special Fracture Number, which aims to present to specialist and general practitioner alike a practical working guide or formula for the management of the more common fractures. The common, uncomplicated fracture is usually handled creditably by the general practitioner, but it must be driven home that complicated fractures in the same region may tax the skill and ingenuity of the expert. To outline the basic principles in the diagnosis, reduction and treatment of the common fractures, to enable the physician to recognize trouble ahead, and to show him the cases and the times when it is necessary for him to seek the cooperation of one more skilled than himself—these are the purposes of this issue of the American Journal of Surgery.

That Dr. Kellogg Speed has shown rare judgment in his selection of authors, and in making the assignment of topics, is evident throughout these pages. To him the publisher and editor desire to express their deepest sense of appreciation. This appreciation of the work which he and his collaborators have done will, we are sure, be shared by every reader who is, in any manner and to any degree, interested in the problems offered by fractures.

T. S. W.

ORIGINAL ARTICLES

EMERGENCY TREATMENT OF FRACTURES OF THE LOWER EXTREMITIES

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FRACTURES of the lower extremities constitute an important group of injuries producing frequent disability, often ending fatally. Slowness of application and lack of proper emergency treatment cause this. The Fracture Committee of the British Medical Association recently reported that when fractures were treated by organized methods, incapacity remained permanent in only 1 per cent of the patients; whereas if the patients were treated by unorganized methods, 37 per cent remained incapacitated. The injuries resulting from fracture are not limited to the time of the accident. Simple fractures are frequently compounded, and irreparable damage is done to the soft parts, through improper handling by well-meaning but inexperienced persons. Far too frequently we see a patient arriving at the hospital with the fractured lower limb practically wrapped around his body. Without doubt he was lifted at the site of the accident with no support to the injured limb: then he was placed in the first available automobile and rushed over roads and streets at a high rate of speed, thereby damaging the limb still more at every jolt or turn.

In fractures of the lower extremities, overriding of the ends of the fractured bone is the usual condition found; for, as soon as the continuity of the bone is broken, nature attempts to splint the part by muscular contraction. An exaggeration of this condition can be prevented during transportation only by the application of a fixed point above and below, so that the traction on the limb remains the same no matter what position the limb or splint may take. To obtain the fixed traction for transporting a patient with a fracture of the lower extremities, it requires the application of a Thomas splint or its modification, the Keller-Blake hinged half-ring splint. The latter is easier to apply and occupies less space in an ambulance or automobile. Traction sufficient to neutralize muscle pull and prevent further damage should be applied before the injured person is moved. Traction properly applied increases comfort, lessens shock, and prevents further damage to the injured limb. It simplifies the work of the surgeon, promotes earlier union, and lessens the danger of non-union. Consequently it reduces the stay in the hospital, thereby reducing cost, and providing an earlier return to work.

The medical profession must realize the importance of prompt and proper first-aid treatment, and see that fixed traction for transportation be generally used in fractures of the lower extremities. Naturally physicians must be thoroughly trained in the fundamentals of first-aid and fixed traction, so they can direct the laity and actively promote better emergency aid to fractures of the lower extremities. Effectual first-aid service of this kind is possible

through the training of those who are brought in contact with accident cases: i.e., ambulance drivers, city police and firemen accident squads, state highway patrolmen, construction, factory, and mine foremen.

"Splint them where they lie" is truly the first principle in the emergency treatment of fractures of the lower extremities.

Fig. 1. Thomas traction splint.

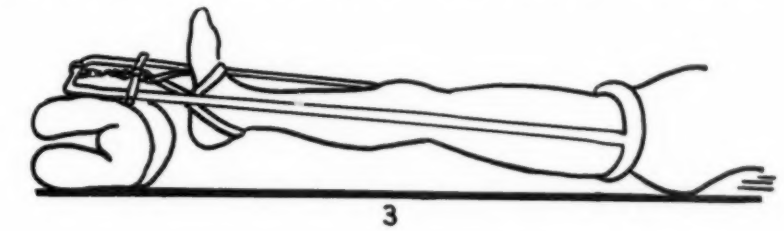
Fig. 2. Keller-Blake half ring traction splint.

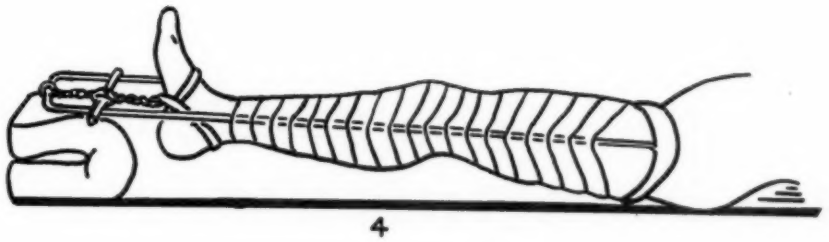
It is necessary for interns to know the principles of first-aid including fixed traction for transportation of fractures of the lower extremities, while serving on the ambulance or in the emergency room at the hospital. The general practitioner also renders emergency treatment to the majority of fractures of the lower extremities; he should be adequately equipped to handle those he is capable of treating; he should also recognize early those he is not equipped to treat. The physician who accepts a fracture case for treatment beyond the emergency should be held responsible for the end-results and not the surgeon nor the orthopedist who sees the case when failure is imminent.

The emergency treatment should begin at the place of the accident immediately after the injury. The type of the initial treatment is of paramount importance, as the problem of the definite treatment of a fracture hinges largely upon it and upon the time of its application.

As already noted, prompt and proper first-aid treatment is an important factor in rapid recovery and the avoidance of permanent disability. It should begin with an examination of the patient's general condition before attempting to splint the fracture or to transport the patient. As a rule it is not necessary to remove any of the clothing at the site of the accident to obtain a satisfactory concept of the injuries and their constitutional effect. If the patient is conscious, he can give the site of the pain. Examination should reveal the pres-

ence of deformity and the loss of function. Extreme care and gentleness are essential in manipulation for diagnosis. Never try to prove a fracture at the site of the accident by trying to obtain crepitus or a false point of motion. If there is a suspicion of a fracture, treat it as such until a satisfactory examination can be made under favorable surroundings and with the assistance of consultants if needed. Always be sure that a second fracture is not overlooked before transporting the patient.





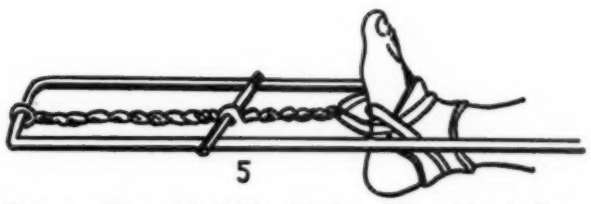
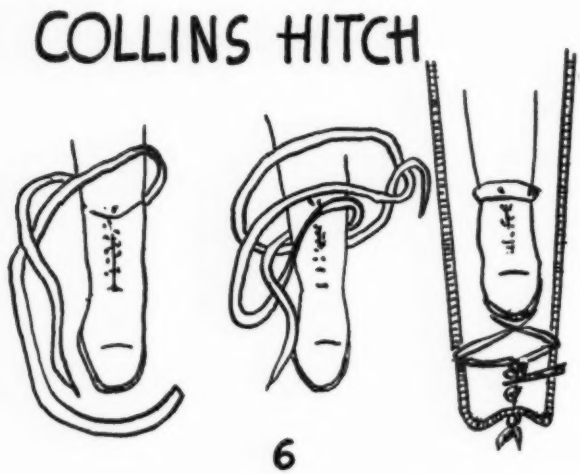


Fig. 3. Thomas splint with Collins hitch and Spanish windlass.
Fig. 4. Thomas splint with Collins hitch and Spanish windlass with the circular bandage applied to give better fixation of the limb.
Fig. 5. Collins hitch and Spanish windlass.

Shock to some degree exists with all major fractures of the lower extremities. Always look for it. The emergency treatment should first combat shock and relieve pain. "First save the life and then the limb." Many lives have been sacrificed through subjecting injured persons with fractures to the shock of reduction and transportation before they have recovered from the shock of the injury. The fixed traction splint should always be applied to the lower extremity before the patient is removed from the site of the injury whenever there is a fracture or a suspected fracture between the ankle and the hip. If a proper splint is not available, the patient should be made comfortable and kept warm; then hand traction must be applied to the limb until a splint can be secured. The splint should be brought to the patient wherever he may be found. Far too frequently the patient is taken to the splint.

Without changing the position of the patient, make preliminary examination to determine the degree of primary shock and the amount of pain suffered. Cover the patient with a blanket to conserve the body heat. If called for, administer morphine hypodermically to combat shock and relieve pain. Then make a careful examination to determine the extent of the injuries. As has been said this usually can be done without removing the clothing, but always cut if it is necessary for diagnosis or for dressing wounds.

If there is a wound or compound fracture, apply tincture of iodine and cover with sterile dressing, if available, before the splint is put on. In compound fractures with projecting bone, apply iodine to the wound and projecting bone ends, and cover with sterile dressings. Do not attempt to replace projecting bone fragments. In case they disappear beneath the skin during the application of the fixed traction splint, no harm will result, for such a patient requires special care as soon as he reaches the hospital or a physician's office, and it is possible to cleanse the entire surface and surrounding area of the wound. With projecting bone ends, there is danger of increasing the area of contamination by the movement of the bone fragments if traction is not applied. It is important that whoever applies traction should observe if the bone is projecting through the wound, and if in the application of traction the bone ends recede, he should report this fact to the doctor wherever the injured person is taken for treatment.



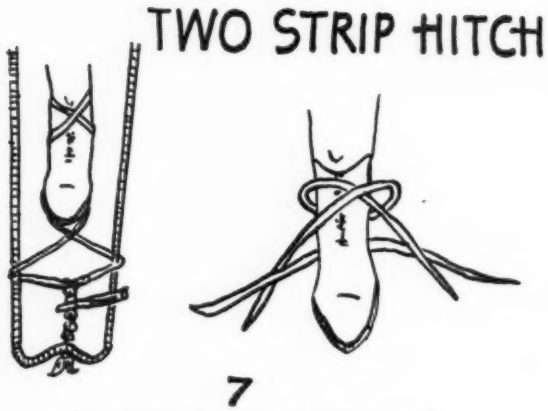


Fig. 6. Application of Collins hitch.
Fig. 7. Application of two-strip hitch.

Bleeding can usually be checked by the application of a firm compression bandage; if this fails, then apply a tourniquet. When a tourniquet is necessary, it must be loosened every half hour to allow for blood supply to the extremity distal to the tourniquet.

With everything in readiness for the application of the fixed traction splint, grasp the ankle and foot of the fractured limb with both hands, placed laterally, with or without the shoe on, and exert gentle but firm steady traction in the axis of the extremity, at the same time slowly lifting the limb from the surface on which it is found. The ring of the Thomas splint is slipped over the foot and up the leg and thigh to rest against the tuberosity of the ischium. The Keller-Blake half ring splint is slipped under the injured extremity from the outer side until the bars of the splint are in the median horizontal plane of the thigh, with the ring resting well up against the tuberosity of the ischium to obtain a point of fixation: then the strap over the anterior surface of the thigh is buckled and tightened. With either splint the lower end should rest against the body of the person who is maintaining the steady traction. The ankle is usually covered with cotton or felt wadding, if it is available, but a high shoe alone will suffice for protection when the traction hitch is applied. This may be an army traction strap, a double Clove hitch, a Collins hitch, or an ordinary 3 or 4 inch cotton bandage tied over the wadding, around the ankle, with a square knot on the outside, and another similar strip around the ankle with the knot on the inside. The long ends of the strap or bandage are carried out over the side rods and tied firmly over the end of the splint. Traction is increased with a Spanish wind-

lass action by means of a tongue depressor, or short stick, which is fastened to the bars of the splint with a strip of adhesive tact with the surface. If the patient has to travel any great distances, it is best to have some sort of foot piece for support. The

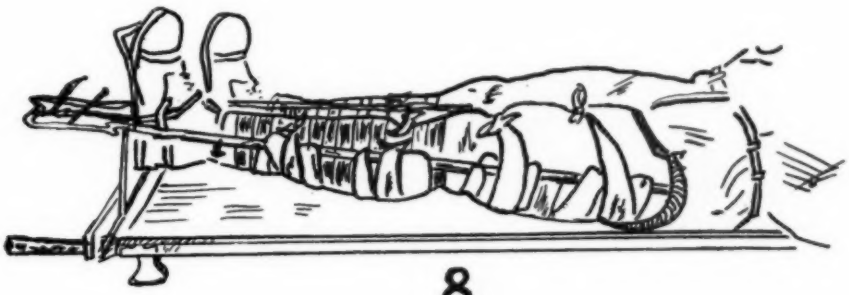


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Fig. 8. Application of Keller-Blake traction splint: U. S. Army method.
Fig. 9. Lister splint for emergency treatment of fracture of the femur.

plaster. When sufficient fixed traction is obtained, manual traction is released.

Support the limb in the splint either with a circular bandage encircling the entire limb and bars of the splint, or by applying five or six triangular muslin slings from the heel to the upper portion of the thigh. If the latter are used, prevent lateral movement by applying muslin bandages above and below the knee or by carrying the triangular slings used for support around the limb and splint. In the application of either of these splints to males, the scrotum must be pushed aside to prevent pinching. The Keller-Blake splint may be applied to the female without exposure. If the fixed traction is to be kept up for any length of time, the circulation of the foot must be watched. Should the circulation be interfered with, the Spanish windlass must be released for a few minutes at half-hour intervals.

Suspend the end of the splint from the stretcher bar or from the roof of the ambulance. Keep the heel free from con-

patient should be transported with care; certainly not at a high rate of speed as is so frequently done. A patient with a fracture and in shock should not be transported any great distance. It is often advisable to apply a fixed traction splint, take him to a house near the site of the accident, put him in a warm bed, and cover with blankets. He should be kept there until he recovers from shock; during this time he must be disturbed as little as possible. Warmth is the most important consideration at this time.

If a fixed traction splint cannot be secured for the emergency treatment of a fractured femur, use a Liston side splint extending from the axilla to beyond the foot. This is bound to the body and the injured limb. An internal long, flat board splint extending from the perineum to beyond the foot should be applied and fixed. After the application of the Liston splint, the well limb should be fixed to the injured one. In case no splints are available, some immobilization can be obtained by

tying the ankles and knees together, thus using the normal lower extremity as a splint for the fractured one. If a pillow is

Fig. 10. Pillow splint for fracture of the tibia, fibula or ankle.

available, place it under the knees and fix it to the limbs. Any splint, however, which does not permit traction should be considered a makeshift.

The emergency pillow splint for fractures of the knee, or the ankle, or of both bones of the leg is most efficient. Use an ordinary feather pillow. While traction is made on the foot, with rotation corrected, the leg is placed on the pillow with the heel about six inches from the end; the pillow is folded up on either side of the leg and pinned tightly with safety pins. The end of the pillow is then folded over the foot and pinned tightly, thus immobilizing the injured part in its corrected position; or padded lateral and posterior board splints, extending beyond the foot, are applied and bandaged to the limb. Fracture of the foot should be splinted so as to protect the heel and the toe from touching any object.

In compound fractures of the knee and ankle no effort should be made to correct the deformity at the site of the injury, because of the danger of carrying infection into the depth of the wound. Cover with a sterile gauze and bandages, then immobilize. The patient should be rushed to the hospital for definitive treatment.

The fixed traction splint should be kept on after the patient arrives at the hospital, during the preliminary treatment, and until definite treatment of the fracture is undertaken. If upon arrival at the hospital, the patient is in shock, he should be placed in bed and treated for this condition. During this time the circulation of the foot should be watched. When the patient has sufficiently recovered from shock, and not until then, a roentgenogram should be taken. If upon arrival at the hospital the

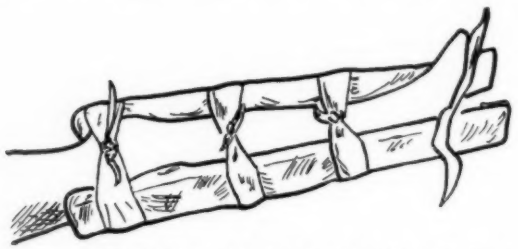

Fig. 11. Padded board lateral splint for fracture of knee, leg and/or the ankle.

patient's condition is satisfactory, he should be taken to the *x*-ray room for a picture. Patients with fractures of the lower extremities arriving in the hospital emergency room without proper splinting, should have a fixed traction splint applied preliminary to examination and treatment. This splint will, of course, be kept on until definitive treatment is undertaken.

CONCLUSIONS

Proper splints for the emergency treatment of fractures of the long bones should be the standard equipment of every physician's automobile, of every ambulance, for every highway patrolman, fireman, and police accident squad, and of every industrial plant, mine, and construction crew.

There is need for a more general use of these splints in fractures of the extremities, and it is the duty of the medical profession to see that they are made available wherever they may be needed.

The final cost of every long bone fracture case will be reduced by more than $100.00 when fixed traction splints are applied properly at the site of the accident before the injured person is moved.

It is important to remember that speed of application, type of first aid, proper fixed traction splinting, and careful transportation are large factors in the ultimate recovery of fractures of the lower extremities.

Even in the emergency treatment of fractures of the lower extremities, we must

have in mind the restoration of functional anatomy.

Immediate reduction of the fracture and the early commencement of definite treatment are important factors yielding satisfactory results.

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"The general terms "osteogenesis" and "osteopsathyrosis" are used to designate a condition in which there is a generalized hypoplasia of the skeleton and in which the bones of the affected individuals are not sufficiently strong to bear the wear and tear of normal existence. In these persons fractures occur from trivial accidents, and, depending upon the degree of hypoplasia, may be very numerous and occur at frequent intervals."

THE PRINCIPLES OF TREATMENT OF COMPOUND FRACTURES*

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COMPOUND fractures, which are becoming increasingly more common in this machine age, are surgical emergencies and demand early and adequate care. Failure to recognize this fact results too often in prolonged chronic infections of soft parts and bone, deformity, permanent disability, loss of limbs, and even death.

Three hundred and fifty-six cases of early compound fractures, of which the majority have been patients at the Los Angeles County Hospital, have been studied in the past few years, and this information coupled with visits to fracture clinics in this country and abroad has resulted in certain opinions relative to the treatment of these cases.

Many cases of compound fractures are first seen and often treated by physicians in general practice. Hence it is important that there should be some unification and an understanding of the underlying principles in the treatment of these emergent cases. It is with this idea in mind that this paper is presented.

There are three major problems to deal with in caring for compound fractures which are: (1) treatment of the patient (shock, hemorrhage, and internal injuries); (2) care of the soft parts injury at the fracture site; and (3) treatment of the fracture.

A compound fracture in general may be one of two types, either direct or indirect. In the former the soft tissues are contused and lacerated by an external force, while in the indirect type the soft parts and skin are punctured from within outward by a sharp bony spicule at the fracture site. All compound fractures are potentially infected, but most writers agree that the indirect type results in a higher percentage of healing per primum. This was so in the series of cases herein reported, for in the indirect compound wounds healing of soft parts by first intention occurred in 86 per cent, while in the direct injuries only 52 per cent healed by first intention. The explanation for this is that in the direct type there is in addition to the grinding in of foreign objects and organisms, laceration and crushing of soft tissues. The indirect variety usually fares better because the skin opening is generally small, soft tissues are not as extensively traumatized, and less foreign material and probably fewer bacteria are drawn into the wound as the bone end recedes. Occasionally there is uncertainty if an injury is compound, but blood containing droplets of fat oozing from the wound indicates as a rule origin from fracture site.

Broadly speaking, the essential difference between a compound and simple fracture is the potential infection which accompanies the former. Every effort must be made to prevent infection and if possible to promote healing per primum, thus eliminating the dangers of local and general sepsis. Early adequate débridement, in order to eliminate devitalized tissue, which forms an admirable culture media for the bacteria present, is requisite to prevent infection. Each added hour after injury that surgery is delayed enhances infection.

The first aid treatment of compound fractures necessarily starts at the place of injury. No attempt should be made to reduce the fracture; instead, the fractured limb should be splinted before moving the patient. Evidence of shock (weak rapid pulse and cold clammy skin) should be

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combated by external heat (blankets, cloths, etc.) and hot drinks and morphine if available. The head should be kept level or lowered. The wound should not be probed with fingers or instruments but should be covered with sterile or clean dressings. Vigorous bleeding at the fracture site may require a constrictor but this should not be used indiscriminately. If it is applied too tightly or for too long a time, serious damage may result to tissues with an already embarrassed circulation, thus increasing the chances of infection and gangrene. The bleeding from compound fractures often stops of its own accord, especially when the limb is well splinted. It is important that the patient be taken as soon as possible to a well equipped hospital.

The patient on arriving at the hospital may be in varying degrees of shock. This must be treated first. External heat is supplied by blankets and hot water bottles, also helpful are hot drinks. Morphine is indicated for pain and restlessness and after its administration symptoms of shock often disappear quite rapidly. Intravenous administration of saline or glucose in saline is of value. With the poor general circulation associated with shock, subcutaneous administration of fluids frequently "water-logs" the area of administration and is very slowly absorbed, hence the intravenous method is preferable. Whole blood transfusions may be necessary and are invaluable.

Other injuries such as to brain, spinal cord, lungs and abdominal organs must be looked for and may require attention before the compound fracture is treated.

All patients with compound fractures should receive tetanus antitoxin, and the usual dosage given is 1500 units. The sensitization of the patient is first tested by 0.5 cc. intracutaneous injection and if the patient is sensitive, the serum is given in divided doses. Four cases of clinical tetanus occurred in this series of 356 cases.

Case I. A white female child of 5 received a compound fracture of the phalanges of the middle right finger which was caught in the cogs of a noodle mixer. The wound was cleaned and dressed but no tetanus antitoxin given. She was admitted ten days later to the Los Angeles County Hospital with inability to open her jaws, difficulty in swallowing and breathing, and spastic neck and back muscles. She was given massive doses of tetanus antitoxin and finally recovered. Infection at the fracture site led to an ankylosed interphalangeal joint.

Case II. A white male of 15 received a compound fracture of right tibia and fibula on a football field. The wounds were cleaned and dressed at a private hospital but no tetanus antitoxin was given. Eight days later he was admitted to the Los Angeles County Hospital with stiffness of back muscles and jaws and great difficulty in swallowing and breathing. He received large doses of tetanus antitoxin intracisternally and intravenously (365,000 units in five days). Recovery followed but a chronic osteomyelitis of the tibia occurred which drained for one and a half years.

Case III. A female Mexican child of 4 sustained a compound fracture of the right great toe when a board fell on it. She was treated by a doctor for eight days, but no tetanus antitoxin was given, and she developed great difficulty in breathing and swallowing, stiff jaws and opisthotonos. At this time she was admitted to the Los Angeles County Hospital. Despite massive doses of tetanus antitoxin intraspinally, intramuscularly, and intravenously, she died three days after admission.

Case IV. A white female of 85 fell in her garden, receiving a compound fracture of both bones of the right forearm. The wound was débrided, closed and a cast applied, and she received 1500 units of tetanus antitoxin. Four days later she developed stiffness in the jaws and difficulty in breathing. Large doses of tetanus antitoxin were given about the wound, intramuscularly and intravenously. She recovered and after some infection the wound and fracture healed.

Of these four cases three had no antitetanic serum until symptoms of tetanus occurred. The fourth case had the serum but even so developed a mild form of tetanus. Daland reported a similar case.

The value of administering a polyvalent gas gangrene antitoxin may be debatable.

The type of prophylactic antitoxin most commonly used is a mixed preparation containing 1500 units of tetanus antitoxin, 2000 units of perfringens (B. Welchii antitoxin), and 2000 units of vibrion septique antitoxin. Forty-nine cases of gas gangrene or infection occurred in the 356 compound fracture cases and of these there were nine deaths. All of these showed positive cultures for gas organisms, principally the bacillus Welchii, and a number of cases are included which had only local gangrene without extension, or at least evidence of gas in the soft parts proximal to the wound. Seventeen of the forty-nine cases received anti-gas serum at the time of initial treatment and of these five died (three from acute gas infection, one with gas infection and pneumonia and the other with gas infection and intra-abdominal injuries). Five amputations with two recoveries were done in this group. Nineteen cases received anti-gas serum only after clinical symptoms of gas infection were present, and of these, twelve required early amputation. Three of these cases died of the infection. Thirteen of the forty-nine cases received no anti-gas serum at any time, and of these, seven required amputation: all survived but one.

All of the gas infections except two occurred in the cases of direct compound injury where tissues were lacerated and crushed. As many of the 356 cases in this series received the prophylactic anti-gas serum early and did not develop a gas bacillus infection, it is not possible to estimate accurately the value of the serum. It probably should be given routinely as a prophylactic measure, especially in the direct compound injuries. Ritter gave it in 100 cases and had no gas infections. On the other hand, Ehalt, first assistant in Böhler's Clinic in Vienna, stated that in over 400 cases of compound fracture there the serum was not given and only one case of gas infection occurred, which recovered with amputation. He said further that gas infections can be prevented if compound wounds are thoroughly débrided and closed in the first six hours, while after six hours the wounds should be left open following débridement, thus exposing any anaerobic organisms to the air.

Draining wounds may yield gas bacilli on smear and culture, and such wounds should be left open, treated with oxidizing solutions, and watched carefully. Local necrosis only may occur, but the patient's general condition must be observed and careful inspection made of adjacent soft tissues for evidence of gas. Roentgenograms are at times useful in detecting gas bubbles deep in muscles that do not yield crepitation on palpation. If the patient's general condition is quite good and gas is present in adjacent muscles, deep linear incisions may be all that is necessary, leaving the wounds open and irrigating them with Dakin's solution or hydrogen peroxide. Further extension of the gas or extensive crepitation in the soft parts with the patient's general condition becoming worse requires immediate high guillotine amputation. Treatment of clinical gas infections should probably include intramuscular injection of repeated and large doses of anti-gas serum and the preparation which was used in these cases, when it was given, was perfringens antitoxin concentrated (20 cc. —10,000 units).

When signs of shock are past and the patient has received antitetanus and gas serum, roentgenograms should be made of the injury and the patient sent to the operating room. Any standard anesthetic may be given and in this series spinal and inhalation anesthesia (ether, ethylene and nitrous oxide) all proved satisfactory and there were no anesthetic deaths. The type of anesthesia is not so important as the amount and method given. Almost any anesthetic if carelessly given will depress the patient—especially one who might have recently been in shock.

Primary amputation is at times indicated (but only after signs of shock are past) when, as Speed has pointed out, the soft parts peripheral to the fracture are lacerated and crushed beyond hope either of

repair or of regaining circulation; when the skin has been stripped from three-quarters of the peripheral part with extensive subadjacent muscular damage, or when important blood vessels are known to be torn across and distal circulation is lost. Also badly crushed and comminuted bony structures as of the foot may require amputation. The patient's condition and the time after injury will determine where and how the amputation is done. Completion of a partial amputation with débridement and leaving the stump open may only be possible because of the patient's condition. A guillotine or flap amputation proximal to the injury with or without closure will be determined by the patient's general condition and the space of time after injury, which, if several hours or more, may have allowed infection to extend proximally in the lymphatics beyond the amputation site. A secondary closure or plastic skin repair is of no serious consequence if the individual's life is saved. Caution should, however, be practiced against needless primary amputations of parts which are warm and have good circulation. Subsequent amputation can be done if indicated. Some extremities, however, are treated for months and months, with a final result either of an extensive chronic infection or a painfully useful or useless limb which requires amputation. This often causes a heavy economic loss either to the patient or the hospital if he is receiving charity service.

The next step is preparation of the skin of the injured limb. This is washed with soap and water, grease is removed with benzine and the hair is shaved, during which time the wound remains covered with an alcohol-soaked, or only sterile, gauze. One of the standard antiseptics may then be applied to the skin or, as was done in a number of cases in this series and as advocated by Koch in treating skin and soft tissue lacerations, the skin is simply rewashed and cleaned with soap and water. The limb is then draped and débridement started. Forceps are used to hold the lacerated edges of the wound and with a scalpel a segment of approximately 0.3 cm. to 0.5 cm. is removed from the wound edge. Instruments are then changed and a careful search made for, and excision of, any additional lacerated tissue. All pockets should be explored and carefully débrided by enlarging the skin opening if necessary. Muscle tissue must be débrided until it is red, bleeds on cutting and contracts when pinched. Small detached bony fragments are removed while larger detached fragments and those attached by periosteal strips should not be removed. Soiled and dirty bone ends may have to be rongeured or chiseled away to clean bone, being careful if possible not to sacrifice too much bone with a resulting gap.

In treating the small indirect puncture wounds the question arises, shall the wound be débrided or left alone? A certain percentage of these cases heal without infection, or minimal infection, if simply dressed and unexplored, but it is better to err on the side of safety; enlarge the wound and do a careful débridement. Speed has pointed out that these wounds are potentially less infected than those caused by external violence, yet some may suck in infection or drag in soiled clothing—hence the cleanliness of the wound is doubtful. Pfeiffer and Smyth also believe exploration of these wounds is advisable after having some severe infections in small wounds that were not explored, of which one was caused by an obscured large piece of stocking drawn into the wound depths through a small skin opening.

Nerves and tendons if severed should be repaired in clean looking wounds that are treated within the first six to eight hours using linen or silk. Some authors oppose primary suture of nerves and tendons but if healing per primum occurs a secondary operation does not have to be done, while if infection occurs and the union sloughs, the condition will be no worse than if the nerve or tendon ends had not been sutured but had become involved in the subsequent infection. No attempt is made to repair

blood vessel injury. Bleeding points are ligated with catgut.

After careful painstaking débridement the wound may be irrigated with copious amounts of warm saline solution, which was usually done in this group and is also advocated by Key. Iodine is not used in these wounds as the antiseptic value is doubtful and harm may be done, as fresh red contractile muscle takes on a "cooked" appearance when iodine is poured on it.

Internal fixation of the fracture by metal plates, screws or wires is not advisable as it may lead to or prolong infection. Some writers (Keenan and Wilson) believe such procedures are permissible, while Besley does not. All cases so treated which have been observed by this writer have been attended with marked bone infections.

Wounds which are carefully débrided within six to eight hours after injury may be closed without drainage and those treated between eight and ten hours may be sutured somewhat loosely to allow for possible wound drainage. Buried suture is not used except for hemostasis and repair of tendons and nerves. All injuries that were closed and had drains brought out through the wounds resulted in infections in this series. The Orr treatment of leaving the wounds open and packing with vaseline gauze is advisable in injuries more than ten to twelve hours old and this treatment is also used in old compound fractures with osteomyelitis. Some surgeons leave the wounds open in injuries more than six hours old and do a secondary suture two or three days later, if no evident infection is present, while others (Pfeiffer and Smyth) follow the Orr method in all cases. Ehalt states that all compound wounds, whether closed or left open, should have dependent drainage with a hard rubber drain inserted, not through the compound wound, but through an incision made in healthy skin. This is removed in twenty-four to forty-eight hours, providing the temperature readings are satisfactory.

Primary closure of the skin in compound wounds may not be possible due to loss of skin in which case tension incisions are made at a fair distance from the wound edges.

Insertion of Dakin's tubes and irrigation with Dakin's solution are used in cases of late wound infections and especially those with positive gas bacillus cultures. The irrigation in these cases is done every two hours and supplemented with interval two-hour irrigations of hydrogen peroxide. The procedure, however, is complicated and is of doubtful value unless all details are rigidly adhered to. Daland claims satisfactory results with this treatment for early and late cases of compound fractures so treated at the Massachusetts General Hospital. Conwell also uses this method.

After the wound has been treated according to indications, the fracture is handled as a simple one. Skeletal traction may be necessary in some cases while in a number plaster casts may be applied. The healing of any wound is enhanced by absolute immobilization. Hence the sooner and more adequately this can be obtained the better. Böhler says that one of the secrets of a good result in compound fractures is absolute and uninterrupted immobilization. Obstruction to circulation by circular casts must be guarded against.

SUMMARY

1. Three hundred and fifty-six compound fractures have been studied and impressions and opinions gained from these cases presented.

2. A compound fracture is a surgical emergency and demands adequate and early treatment. This must be directed first to the patient's general condition (shock), then to soft parts injury and finally to the fracture.

3. Indirect or puncture compound fracture wounds result in a much higher percentage of healing per primum than in the direct type.

4. Tetanus antitoxin should be given routinely as a prophylactic measure. Four cases of clinical tetanus are reported.

5. Forty-nine cases of gas bacillus infection with twenty-four amputations and nine deaths are discussed.

6. Primary amputation is indicated in some cases.

7. Compound fracture wounds, both direct and indirect, should be carefully debrided both as to soft tissue and bone, and iodine is not used thereafter. The wounds treated six to eight hours after injury are closed without drainage, while those eight to ten hours old are closed loosely to allow for wound drainage. Wounds more than ten to twelve hours old are packed open with vaseline gauze after excision of traumatized or necrotic tissue. Treatment with Dakin's solution and alternating irrigations of hydrogen peroxide is used in cases of gas infection.

8. Severed nerves and tendons are sutured primarily in cases treated within six to eight hours. Other buried suture is not used in compound wounds except catgut for bleeding vessels.

9. Internal fixation with metal plates, screws and wires is not advisable.

10. Early reduction of the fracture and immobilization are necessary.

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FRACTURES OF THE JAWS AND THEIR MANAGEMENT

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IT must be agreed at the outset that the answer to any medical or surgical problem is the patient himself. His physical and mental well-being, and his complete recovery from disease or disability, are the ends sought. Whatever procedures contribute most rapidly and efficiently to these ends determine the treatment.

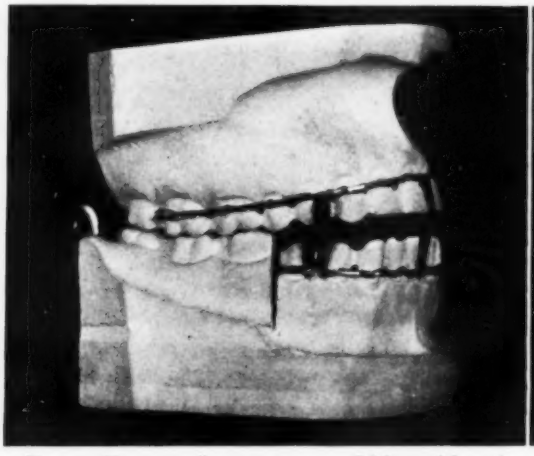


FIG. 1. Fracture between second bicuspid and first molar. The same appliance is used for fractures anywhere between the third molar and lateral incisor.

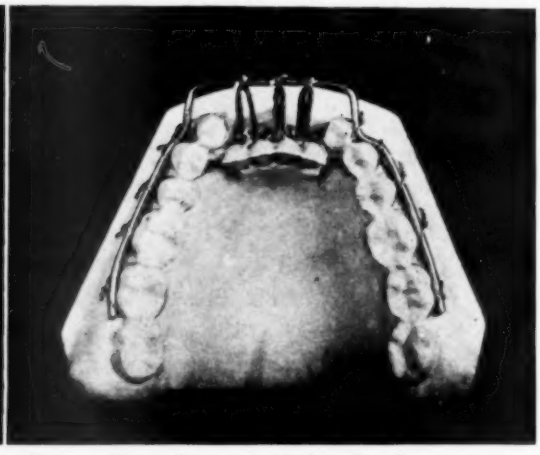


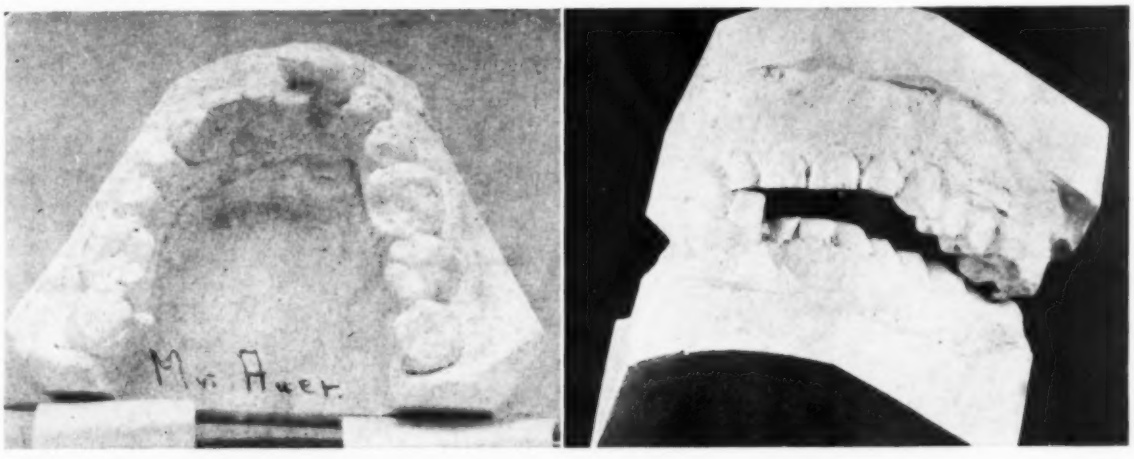
FIG. 2. Deep fracture of the alveolar process with the four incisor teeth carried backward and upward.

Fractures of the jaws necessarily differ from fractures elsewhere in the body. Their structure and function present a problem: occlusion of the teeth must be restored or the fracture has not been successfully managed; the majority of jaw fractures are compound and these cannot be sterilized nor can sterile dressings be applied; fractures usually involve tooth roots which greatly increase the liability of infection. When fractures occur elsewhere in the body, immediate reduction and immobilization are paramount, but when the jaws are broken and the fragments displaced, such a procedure is frequently impossible. Here gradual reduction is the only method possible. Again, the beginning of treatment is often postponed for days or even weeks because of other correlated serious injuries to the body or head. The management of such fractures then calls for definitely specialized skill.

Briefly, then, the methods here outlined we consider to be the best known means of managing fractures of the jaws no matter what the type or extent of injury. The orthodontist has shown that mechanical irritation resulting from the pressure used in moving teeth, stimulates the activities of the osteoblasts and osteoclasts, a principle of first importance in the management of old fractures. By means of elastic traction properly applied the necessary reductions are obtained and physiologically maintained.

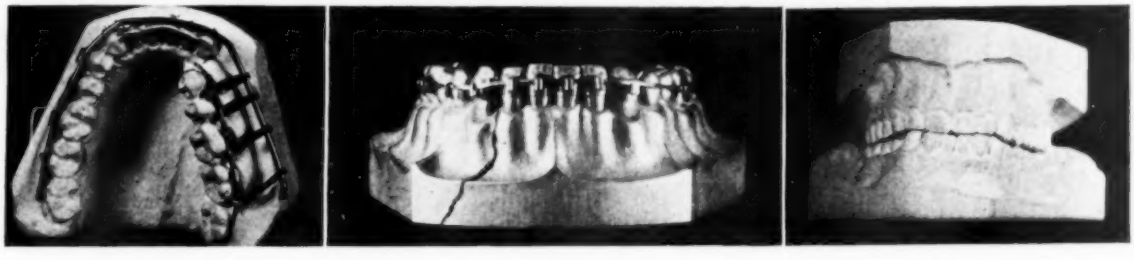
My purpose in this thesis will be served best by illustration of types of fractures and their treatment by this method. We employ elastic traction in almost all cases where reduction is required. The method serves equally well for stabilization. The parts are brought into proper relation

and held with slight movement which aids the process of repair. Complete immobilization retards repair; this is often illustrated in leg and thigh fractures. These factors, combined with the ease and simplicity of its use, we believe prove the value of the method.



A B

Fig. 3. A, fracture seven weeks old, with over-riding fragments. B, extent of deformity.



C D E

Fig. 3. C, type of appliance employed. D, type of retaining appliance particularly adapted to the lower jaw. E, complete restoration of occlusion.

It is not our purpose in this argument to mention or discuss the older methods which are so well known, but rather to emphasize in contrast the value of this method viewed from any angle. In this discussion we shall not attempt to enumerate all the details in the management of jaw fractures, but will be content with illustrating the principle of elastic traction in a more or less general way. Anyone familiar with the management of fractures will at once be able to manage any particular case as the conditions indicate.

The most frequent fractures of the jaws occur in the mandible, and, in turn, the commonest of these lie between the cuspid and the angle of the jaw including it. Fractures of the ramus and condyle occur less often and usually require no treatment unless displacement occurs. The average patient will exercise proper care when he is informed of the fracture and its location. As a matter of fact, we frequently do not apply any treatment in jaw fractures where there is no displacement except to guard against infection. Fractures between the cuspids are usually accompanied by others in the bicuspids and molar regions and at the angle.

The commonest fractures of the upper jaw are associated with the incisors and cuspids involving the alveolar process, loosened, broken or dislocated teeth. This type of fracture rarely involves the jaw itself. In such cases the alveolar process may be molded to place and the teeth retained by silk ligatures applied in the well known figure-of-8 type. When roots are fractured, or the pulps of the teeth involved, the care of the teeth falls naturally to the hands of the dentist. The

application of traction in the treatment of total or unilateral fractures of the maxilla will be demonstrated.

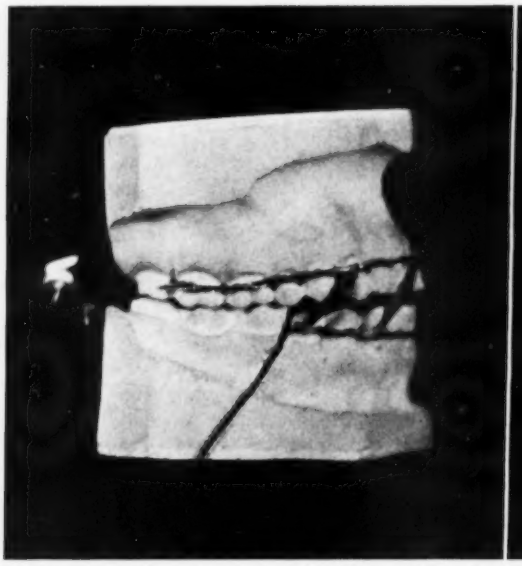


Fig. 4. Angle of traction in direct line of fracture.

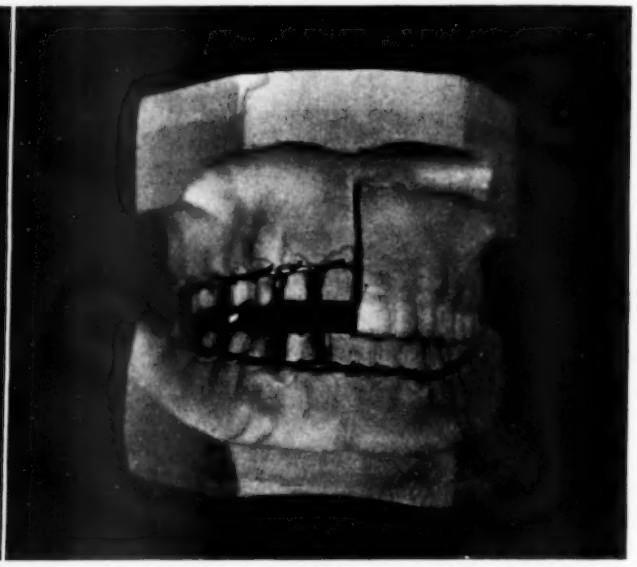


Fig. 5. Unilateral fracture of the upper jaw with downward displacement. This shows traction appliance attached to sound side, forcing the broken fragment into position.

Figure 1 shows the common type of fracture, but it represents as well fractures occurring from the cuspid to the third molar. The position of the fragments shows muscle action, and in all cases the long fragment is down and the short fragment up. Reduction is easily obtained by the simple appliance shown. Angle's ribbon arch wire .022 × .036 is fitted to each arch and fastened to the necks of the teeth with wire and silk ligatures. Angle's ligature wire is used to attach the arch wire to the bicuspids and molars. Dental floss is used for the incisors. When it can be avoided, the cuspids are not used because the necks of these teeth are not in line with the necks of the incisors and bicuspids. When bands are used, the bicuspids are employed. When conditions permit, plaster casts are made of both upper and lower arches and the arch wire fitted to the models. If the condition does not permit this the arch wire can be fitted in the mouth. When the arch wires are in position, orthodontic rubber bands are attached to the upper and lower arch wires as shown with silk ligatures. When full occlusion is obtained, the pull stops automatically and the appliance then holds the bones in proper alignment. Appliance may stay in position until union has taken place. The bands may be removed after two or three weeks to see if occlusion persists without help. If it does, the appliance may be taken off.

Figure 2 represents a rather unusual type of fracture and illustrates a different type of appliance. In this type of case a slightly heavier wire than the one shown in Figure 1 is needed. The wire is fitted to the arch and extended forward from the cuspids to provide the space necessary for the use of rubber bands. The teeth in the displaced fragment may be driven backward in line with the occlusal plane or the segment may be driven backward and upward or backward and downward. It will be seen at once that the position of the wire will need to meet the necessary angle of pull. To meet this the wire may be bent at the cuspid either up or down as the angle of traction requires.

Figure 3, A and B, reproduces a seven week old fracture at time of treatment. The marked over-riding of the fragments complicated both reduction and immobilization. The type of appliance used is

illustrated in Figure 3C. Fortunately there was no bony union and the reduction was complete in two days. The appliance was kept in place for four weeks when an Angle band ribbon arch was used as shown in Figure 3D. This retaining device is particularly useful when the patient is engaged in manual labor. It permits full use of the jaws for eating a full diet and for speech. Figure 3E is a plaster model of the complete case. These figures illustrate one of the most difficult of fractures managed easily and successfully by traction; in fact, it would be difficult to manage such a fracture by any other method.

Fig. 6. Skull and chin caps made of starch bandage, used in total fracture of the upper jaw with downward displacement. These may also be used in fractures of the edentulous lower jaw, using the patient's dentures as guide.

Figure 4 shows the proper direction of the elastic pull. It should be directly in the line of fracture as illustrated. At this point I would stress the use of all teeth possible to the case for the distribution of stress to avoid the danger of overload to individual teeth. As many teeth as possible should be fastened en bloc.

Unilateral fractures of the upper jaw with downward displacement are illustrated in Figure 5. The appliance is put on the side opposite to the fracture. Traction on the sound side will force the displaced part upward until full occlusion is reached.

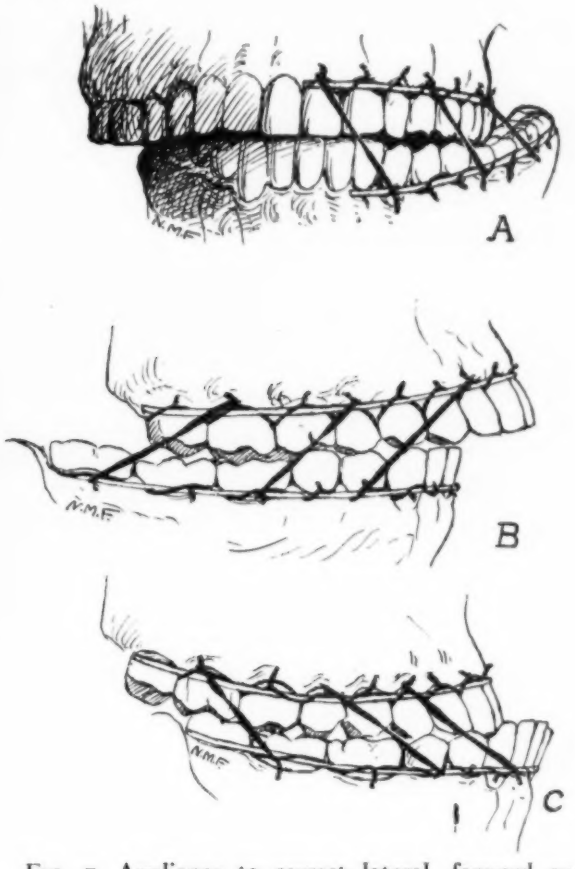
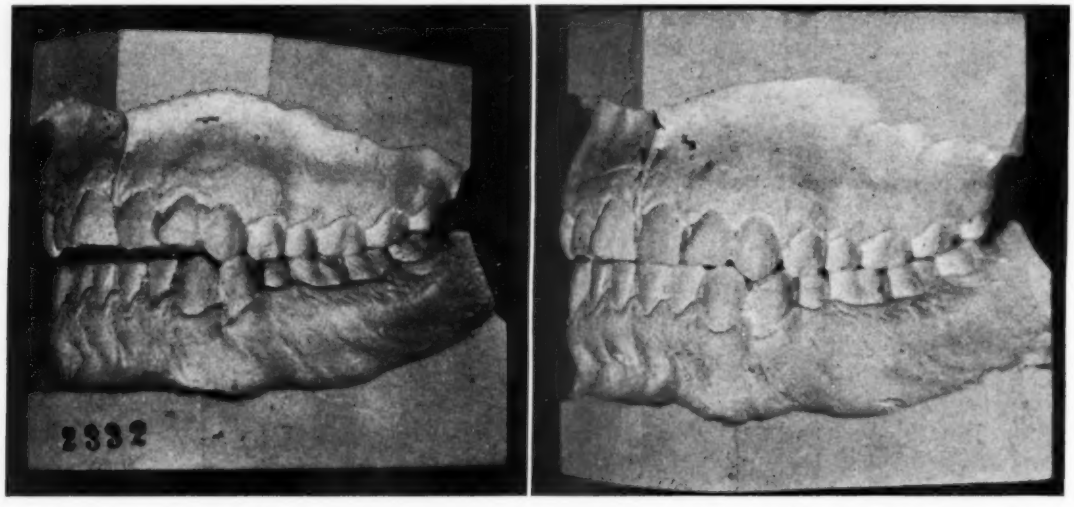


Fig. 7. Appliance to correct lateral, forward or backward displacement in total jaw fractures.

Total fractures of the upper jaw with a downward displacement are managed with a device as shown in Figure 6 with skull and chin caps. It is advisable to make the skull and chin caps out of starch bandage because, in the first place, they are much lighter, and in the second place, the skull cap does not produce as much heat as a plaster cap. The skull cap may be perforated freely to avoid overheat. Hooks from the ordinary hook and eye are attached as shown in the illustration. If it is found upon traction that the displacement is backward, forward or lateral, the correction can usually be made by manipulation. If correction, however, does not take place, the simple appliance used is shown in Figure 7. This type of management is equally usable for fractures of

edentulous jaws. The patient's dentures are used if not too badly broken; in that case, the dentist will quickly and easily make splints which can be used in place of dentures.



A B

FIG. 8. A, deformity of lower jaw fracture seven months old. B, complete restoration of occlusion.

In old fractures—those that are united or partially united—the orthodontic appliance made by the orthodontist or the dentist skilled in orthodontia becomes necessary. A single case is illustrated in Figure 8, A and B. This fracture was approximately seven months old when treatment was undertaken with the cooperation of Dr. Allan G. Brodie, orthodontist. This patient had lost 40 pounds and was most uncomfortable. The description of management by Dr. Brodie is in his own words.

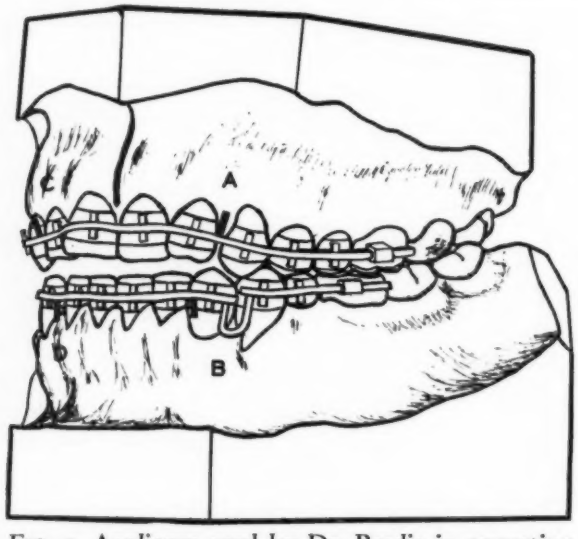


FIG. 9. Appliance used by Dr. Brodie in correcting deformity shown in Figure 8A.

"A full appliance was placed with bracket bands on all teeth as shown in Figure 9. An arch bar .022 × .028 inch was formed to lie passively in all of the upper brackets and tied in place for anchorage. The lower arch bar was likewise made to fit the normal dental arch, but was equipped with a spring loop at B, the site of the fracture. The arch itself was cut at this point, the loop permitting of some movement between the two segments when the arch was tied in. Only one small elastic was looped over the spurs at A and B for traction, and the case was dismissed for one week, the intention being to increase the traction at that time.

"When the patient reported at the specified time it was found that the ends of the arch segments in the loop now coincided, showing that the segments had once more been brought to their proper level. This change had occurred within thirty hours after the first appointment. The lower arch bar was replaced by a solid one to act as a splint. The occlusion was found to have improved considerably, but was still slightly open in the incisor region. Traction was accordingly increased by the addition of an elastic between the spurs at C and D. The patient was now

entirely comfortable and beginning to eat some solid food. He was still highly apprehensive.

"Three weeks later it was found that the bite condition had not changed, and a survey at this time revealed that the upper arch had narrowed almost one-eighth of an inch over the seven preceding months, so that the cheek teeth were striking cusp to cusp, thus preventing complete closure.

"The upper arch was expanded by orthodontic means over the next three months, during which time the incisors gradually closed. All appliances were removed on September 14, 1935 and records were taken. The occlusion at this time was restored to normal."

This case is presented to emphasize the efficiency of traction in reducing fractures that resist other methods, and to stress the necessity of the method itself. This calls for cooperation between the orthodontist or the dentist with orthodontic training and the surgeon, a feature so essential that proper service cannot be rendered without it. Their distinct skills should, by all means, be cooperative.

In closing let me refer again to infection. We know that a large majority of fractures of the jaws are compound and likely to be infected. We also know that the mouth is the habitat of many infective agents. The mouth must be thoroughly cleansed and kept so as nearly as can be. Likewise there must be regular irrigation of the wound. A fine pointed syringe such as the Berlin abscess syringe is recommended. The point may thus be inserted into the wound and into the break of the bone. An iodosaline solution is used twice daily until danger of infection is passed. The solution is made by adding ten to fifteen drops of tincture of iodine to four ounces of a normal salt solution.

Speaking from an experience of several years in the use of elastic traction in the management of fractures, I am convinced that it is the method of first choice. When the patient's comfort, both physical and mental, and the results are considered, that conviction stands.

DISLOCATION OF THE MANDIBLE

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THE temperomandibular joint is frequently the site of pathological lesions which either entirely impair the normal function or render the use of the jaw most difficult. Among these lesions might be mentioned ankylosis, fractures and dislocations. It is with the last mentioned condition that this paper will be concerned. Complete dislocation and the more common form of joint derangement, subluxation, are often a source of great annoyance and the cause of much distress and embarrassment to those so afflicted. The principal complaint is not always of pain, though it is frequently present, but rather of interference with the normal physiological acts of mastication and talking. A survey of the literature on this subject reveals a paucity of information.

Familiarity with the anatomy of the temperomandibular joint is most pertinent to a proper study of its movements and to a correct interpretation of the nature of the disturbances which affect its function. Therefore, a brief anatomical review may not be amiss.

ANATOMY

The temperomandibular articulation is is a ginglymo-arthrodial joint of a highly specialized nature. Capable of producing movements of both a hinge-like and gliding type, it is composed of the condyle of the lower jaw and the mandibular fossa of the temporal bone. The fossa or glenoid cavity, which serves for the reception of the condylar head, is bounded anteriorly by a bony projection known as the articular tubercle; posteriorly, it is separated from the external auditory meatus by the tympanic plate. The articular capsule is a thin loose envelope attached above to the circumference of the mandibular fossa and in front to the articular tubercle; below, it is inserted into the neck of the condyle. Placed between the condyle and the mandibular fossa is the articular disk or meniscus which is intimately adapted to the condyle. Its fibers are joined to the articular capsule and to the tendon of the external pterygoid muscle. The meniscus divides the joint into two cavities, each of which contains a synovial membrane. The upper membrane, which is the larger of the two, is continued from the margin of the cartilage covering the mandibular fossa and the articular tubercle on to the upper surface of the meniscus. The lower one passes from the under surface of the disk to the neck of the condyle, being extended a little farther downward behind than in front.

In addition, three ligaments play an important part in the movements of this joint. The stylomandibular extends from near the apex of the styloid process of the temporal bone to the posterior border of the mandible; the temperomandibular or external lateral, which is attached above to the zygomatic arch and to the lower border of the tubercle, runs downward and backward to be inserted into the lateral surface and posterior border of the neck of the mandible; and the sphenomandibular ligament is attached above to the spina angularis of the sphenoid bone and below to the lingula of the mandibular foramen. The main function of these ligaments is to aid in confining condylar movements to the mandibular fossa and to prevent posterior excursion of the condyle. That there is not an equal degree of traction exerted to prevent anterior displacement, is borne out by the more frequent occurrence of forward dislocation.

This complex articulation can produce movements which are both numerous and varied. "Thus the mandible may be de-

pressed or elevated, or carried forward or backward; a slight amount of side-to-side movement is also permitted. When the

Fig. 1. Unilateral dislocation of mandible. The right condyle has moved forward from its normal position in the mandibular fossa. The symphysis is deviated toward the unaffected side. Occlusion of the teeth is unnatural.

mouth is but slightly opened, as during ordinary conversation, the movement is confined to the lower of the two joints. On the other hand, when the mouth is opened more widely, both joints are concerned in the movement; in the lower joint the movement is of a hinge-like character, the condyle moving around a transverse axis on the disk, while in the upper joint the movement is of a gliding character, the disk, together with the condyle, gliding forward on the articular tubercle, around an axis which passes through the mandibular foramina. These two movements take place simultaneously, the condyle and the disk move forward on the eminence, and at the same time the condyle revolves on the disk. When the condyle is carried horizontally forward, as in protruding the lower incisor teeth in front of the upper, the movement takes place principally in the upper joint, the disk and the condyle gliding forward on the mandibular fossa and the articular tubercle. The grinding or chewing movement is produced by one condyle, with its disk gliding alternately forward and backward, while the other

Fig. 2. Bilateral dislocation of mandible. Both condyles resting on articular tubercles. Lower jaw anteriorly displaced. Impossible to occlude the teeth.

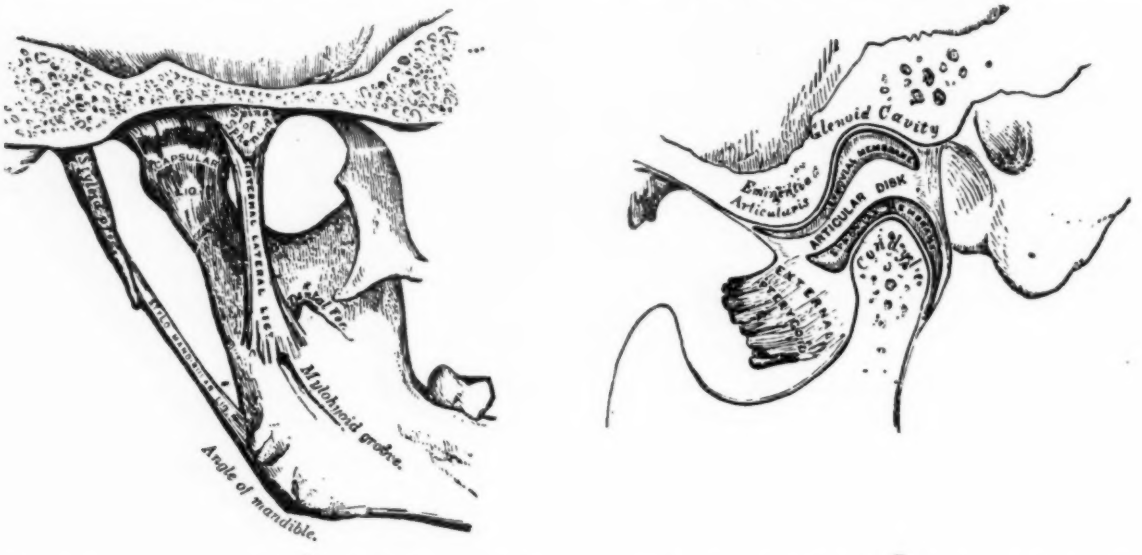
condyle moves simultaneously in the other direction; at the same time the condyle undergoes a vertical rotation on the disk. One condyle advances and rotates; the other condyle recedes and rotates, in alternate succession." (Gray.)[1]

ETIOLOGY

Any unusual force applied to the face may produce, not only a fracture of the jaw bones, but dislocation of the condyle. Displacement of the condyle from its normal position in the mandibular fossa may also be caused by the act of yawning, vomiting or crying. When the jaws are opened widely, as in examination of the oral cavity or during the removal of teeth, there is the possibility that dislocation may occur.

That varying degrees of luxation existed was first recognized by Sir Astley Cooper in 1822.[2] Subluxation, as he termed it, is far from being a rarity at the present time. Though no statistical evidence is available for the statement, it appears that this condition occurs more frequently in young women than in any other group.

The "snapping or clicking" sound emitted as the jaws are opened is audible to the patient and frequently to those nearby.



A B

FIG. 3. A, temperomandibular articulation, medial aspect. B, sagittal section of the articulation of the mandible. (From Gray's Anatomy.)

The specific etiologic factor concerned with dysfunction of the joint is not always clearly defined and has been the cause of much speculation. Cooper was of the opinion that the lesion consisted of a separation of the meniscus from the condylar head, the latter being carried forward leaving the disk cartilage remaining in the fossa. Pringle[3] advanced the idea that the internal pterygoid muscle dragged the meniscus out of its normal position; especially was this prone to take place, he contended, during the act of sneezing or yawning. The tendency to recur was attributed to a general relaxation of the ligaments of the joint, making it difficult to maintain the correct position when the mouth was opened widely. Morris[4] concurred in the peri-articulation theory and believed that the movable disk became crushed between the opposing bony surfaces and that painful locking of the jaws was a natural consequence. We are of the belief that a generalized state of lowered resistance may be an important factor in causing a looseness of the joint tissues.

SYMPTOMS

Though dislocation may occur backward, upward or outward, the most commonly seen is the forward type which may be either single or bilateral. The symptoms of unilateral dislocation are inability to occlude the teeth, deviation of the chin toward the unaffected side, prominence of the head of the condyle and tenseness of the masseter muscle on the side involved. Displacement of both condyles is characterized by an extreme anterior position of the chin, inability to close the mouth, difficulty in swallowing and increased salivation. Roentgenograms of the condylar regions reveal the pronounced forward location assumed by the condyles. Cases of incomplete dislocation do not always exhibit symptoms of an acutely painful nature. However, the constant "clicking" of the jaw often becomes increasingly distressing. Because of the difficulty encountered in the mastication of food, mealtime loses some of its attractiveness.

TREATMENT

The treatment depends on the specific cause of the joint derangement and the degree of dislocation. In a general sense,

whatever method is employed should result in confining the future excursions of the condyle to the mandibular fossa and relieve the patient of the annoying clicking sounds.

Complete dislocations can be reduced by digital manipulation. The easiest and simplest method is to reverse the order of the dislocation, carrying the condyle through the course it took in becoming displaced. The body of the jaw is grasped on each side, the thumbs being in contact with the occlusal surfaces of the lower molar teeth. While downward pressure is exerted on the posterior part of the mandible, the jaw is carried backward, thus enabling the condyle to pass under the articular tubercle and to lodge again in the glenoid cavity.

The treatment of cases of subluxation are divided into two general classifications: (1) surgical and (2) non-surgical. When the condition is traceable to such factors as unbalanced occlusion of the teeth, or to an improper bite of artificial dentures, attention should be directed toward correcting these faults. Many cases of subluxation respond favorably if the jaws are immobilized for a few weeks. Head and chin bandages utilized for this purpose possess several disadvantages. More effective and less conspicuous means are available in the application of intraoral methods of wiring the teeth as used in the treatment of fractures of the jaws.[5] When these conservative procedures do not result in a cure, resort to surgery is the only alternative. Various types of operations have been employed.

Nieden,[6] with a view to preventing recurring dislocation, transplanted a strip of the temporal fascia to the condyle. Tension was made sufficient to retain the head in the fossa. Konjetzny[7] obtained satisfactory results by freeing the fibrocartilage posteriorly and then concentrating it in the anterior part of the fossa in such a way that it acted as a barrier against further displacement. Mayer,[8] under local anesthesia, exposed and studied the joint. In one case simple removal of the meniscus was followed by relief. However, in three other cases preliminary removal of the disc did not prevent the condyle from taking an abnormally forward position. Therefore, in order to deepen the fossa and make dislocation a mechanical impossibility, he utilized the bone-block operation. This consisted in sectioning part of the zygomatic arch and mortising it into a previously cut groove in the temporal bone just anterior to the articular eminence. Then the jaws were fixed from four to six weeks in order to permit healing of the graft. In one case reported by Blake,[9] the coronoid process was bridled to the zygomatic arch by means of a silver wire.

In exposing the joint, consideration should be given to avoiding injury to the important structures in this region and to preserving cosmetic requirements. The facial and auriculotemporal nerves and the superficial temporal vessels follow a course external to the condyle, while the internal maxillary artery lies on the medial aspect. Three general types of incisions may be utilized. The inverted L consists of joining a horizontal incision made along the zygoma with a perpendicular one made just anterior to the tragus of the ear. The second type is formed by carrying the incision posteriorly along the zygomatic arch and then running it upward and backward over the base of the ear. The third type is the simple vertical incision which extends just in front of the external auditory meatus.

In addition to surgical intervention, the injection into the joint of such agents as iodine and alcohol has been tried as a means of stimulating adhesions and consequently limiting the excursions of the condyle. Some degree of success has resulted from such procedures.

SUMMARY

Dislocation and subluxation of the temperomandibular joint are not uncommon occurrences. The majority of cases are due to a lesion of the joint. A loose meniscus

or relaxed ligaments are the principal pathological factors. Treatment has as yet not attained a state of standardization. Conservative methods, such as immobilizing the jaws for a period of a few weeks, should first be employed before resorting to radical procedures. Correction by means of surgical intervention is based on eliminating the specific cause of the dysfunction. Because subluxation of the temperomandibular articulation has not received the same degree of study and observation as have other joints, there exists a fertile field for further investigations.

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"Since tertiary syphilis frequently attacks the skeleton, it is popularly regarded as one of the principal causes of pathologic fractures, and of delayed nonunion after fractures. As a matter of fact, syphilis may almost be disregarded as the cause of either of these. It is, of course, possible that a large gumma may so weaken a bone that a fracture will occur with relatively slight violence, as in the clavicle."

FRACTURE OF THE CLAVICLE

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ANATOMICAL

THE clavicle is a semi-flat S-shaped bone, articulating mesially with the sternum, laterally with the acromial process of the scapula and acting as a strut between these two bones forming the bony support of the shoulder girdle. The mesial end is secured to the sternum by a capsular ligament and an interarticular fibro-cartilage, and to the first rib by rhomboid ligament. (Fig. 1A.) The lateral, or acromial end, is securely tied to the scapula by the coracoid-clavicular and the acromial-clavicular ligaments. (Fig. 1B.) The upper surface of the bone is subcutaneous and palpable for its whole length. The sterno-cleido-mastoid is inserted into the upper edge of the inner third and pectoralis major to the lower anterior surface. The trapezius, posterior, and the deltoid, anterior, find attachment to the outer third. Underneath lies the subclavian muscle which intervenes between it in its middle third, the subclavian vessels, and the brachial plexis.

CAUSATION AND TYPE

The usual site of fracture is the outer half of the middle third, where the long anterior and short posterior curves meet—where it is structurally weakest, and is not fixed or supported by muscles or ligaments.

Fracture of the clavicle is one of the most common of all fractures, particularly in children. It is usually incomplete or of the greenstick variety. In adults, the fracture is nearly always complete and may be comminuted, but is rarely compound except in gunshot or direct crushing injuries.

Indirect violence is the usual cause; i.e., from a fall on the extended hand, elbow, or shoulder with the arm in abduction. The shoulder is violently elevated by the transmission of the force. The sternal end of the clavicle being fixed by the strong rhomboid ligament fractures occur at the weakest point of the bone.

Direct violence may cause fracture by compression, being usually received on the most prominent part of the bone; at its convexity forward in the inner third, or on its acromial end.

Muscular action is at times a cause, although rarely.

Deformity, of course, must come under this heading, and site of fracture be considered.

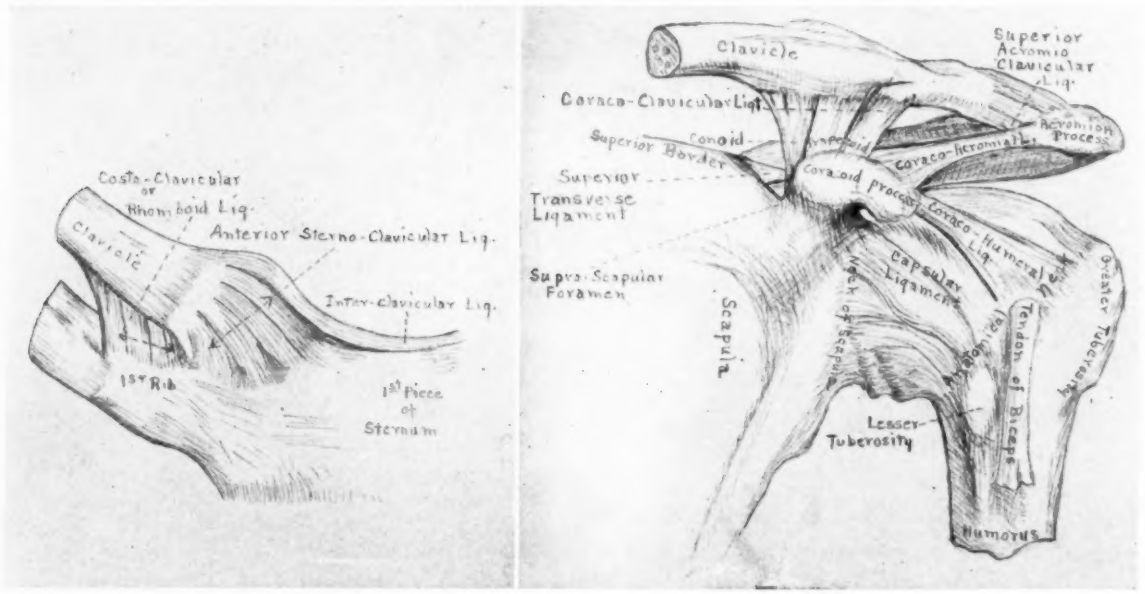
In infants and children, the fracture may be easily missed. The patient does not use the arm, complains of pain and tenderness, and palpation may reveal a slight angular deformity directed forward and upward in the middle third of the bone.

In adults, when the fracture has occurred in the mid-portion of the bone, the patient presents himself supporting the flexed forearm of the injured side in his well hand. The strut of the shoulder girdle having collapsed, the shoulder drops downward, forward and inward from the effect of gravity and the action of the pectoral and latissimus dorsi muscles.

The distal fragment, being fixed to the scapula by the coraco-clavicular and acromio clavicular ligaments, moves downward, forward and inward. The proximal fragment is displaced slightly upward by the sterno-cleido-mastoid muscle. The fragments override, and the width of the shoulders is lessened.

Acromial end: Fractures here are usually the result of direct force, or indirect thrust upward with the arm in abduction. If the fracture occurs between the coracoid and trapezoid ligaments there is little or no displacement, as both fragments retain their ligamentous fixation. If the line of fracture is distal to the coracoid-clavicular

ligament, and the result of direct violence, the deformity may be angular—the scapula rotating forward—or the fragment may be driven downward, particularly if the acromio-clavicular ligament is torn.



A B

FIG. 1. The clavicle is secured to the sternum by the ligaments of the sternoclavicular joint and fixed to the first rib by the strong rhomboid ligament. The outer third is still more securely anchored to the scapula by the coracoclavicular ligament and the ligaments supporting the acromioclavicular joint.

DIAGNOSIS

There is pain, tenderness, and usually deformity at the site of fracture, with loss of the use of the arm if the fracture is complete. The attitude is characteristic, as cited above, the shoulder having dropped downward, forward and inward, causing a definite narrowing of the shoulder breadth: the head is held toward the injured side. *X*-ray confirms the diagnosis of fracture, its location and type.

TREATMENT

Reduction of the usual fracture is not difficult, but the maintenance of reduction becomes the problem, as the weight of the shoulder girdle must be borne by the soft parts of the axillary fold when ambulatory treatment is employed.

Reduction is rendered painless if 10 to 20 cc. of a 2 per cent novocaine solution is injected into the fracture line, which is subcutaneous, if the operator waits ten minutes by the watch. The shoulder is brought upward, backward and outward, correcting the deformity and the overriding. The bone ends are manipulated into alignment by direct digital pressure.

In children the fracture is usually incomplete, the deformity being anterior and upward. Here direct pressure exerted downward and backward over the deformity, while the shoulder is forced forward and upward, will be necessary to correct the deformity.

Open reduction is rarely, if ever, indicated unless the fracture be compound, when a thorough débridement should be done. Fractures of the outer third, with marked displacement, may at times necessitate open reduction.

Various methods have been used in the past to maintain the reduction: we have the Sayre, Valpeau and other types of dressings which secure the arm and forearm to the chest wall. They rarely accomplish their purpose, and cause increased atrophy and stiffness in the extremity and discomfort to the patient. These have been discarded as unsatisfactory.

The "T" splint (Fig. 3) meets the requirements of ambulatory treatment better than any other appliance, allowing free motion of both arms. The splint is easily applied and adjusted. Its application to a patient with a round back is difficult.

The "T" splint is formed by mortising and fixing with rivets or screws the end of one piece of maple or hickory wood 3 inches × ⅜ inch × 18 inches with the middle of the other similar piece. Straps of 1½ inch non-elastic webbing and 1½ inch steel buckles are secured to the splint by carpet tacks, as indicated in Figure 3.

The wooden splint is well padded with saddle felt or cotton gauze pads held in place with adhesive, and the straps which cause pressure over the abdomen and axilla are likewise padded with saddle felt covered with stockinette, secured in place by sewing.

It is well to have made up and available for use splints measuring 20 inches in length for the broad-shouldered, long-back individual, and 16 inch lengths for the smaller patient.

For infants and young children, the "T" splints are made of bass-wood splint board, cut the size indicated, tacked together and padded. The shoulders are fixed to the splint and the splint to the patient with Canton flannel bandages and adhesive.

Application of splint: The fracture having been reduced, with the patient sitting on a stool, the splint, after proper padding, is applied to the back with the transverse arm above the shoulder level. The abdominal strap is secured to the lower buckles on the vertical arm and made secure. The inner straps attached to the transverse arm of the splint are brought up *under* the splint, over the shoulders at the base of the neck, crossed on the anterior chest wall, and secured to the upper buckles on the lower end of the vertical arm of the splint. These straps, with the abdominal strap, fix the splint to the patient's back and form a "hitching post" to which the shoulders are "tied." The shoulders are now secured to the outer end of the splint by the outer padded strap which passes under the axilla, holding both shoulders upward, backward and outward.

Fig. 2. Usual site of fracture of the clavicle at its weakest point, showing the characteristic deformity.

The straps are adjusted as indicated, and may be loosened while the fractured extremity is supported and the underlying skin cared for daily. Pressure downward and backward may be exerted on the proximal fragment by placing a pad under the retaining strap of the splint which crosses it. The arms are left free and stiffening of joints, therefore, does not occur. If swelling occurs due to pressure of the shoulder supporting straps over the axilla, it is quickly relieved if the patient lies down and elevates the arm.

Recumbent method: Probably the best way to maintain reduction with a minimum of deformity is by recumbency. The patient is placed on a hard bed with a small sand

bag between the shoulders; the elbow is raised and supported on a sand bag; the wrist is fixed to the neck by bandaging, and the arm steadied by sand bags. This régime becomes rather irksome to the patient, however, as it must be continued for a minimum of three weeks. Nursing care is therefore difficult.

PROGNOSIS

Consolidation usually occurs in three to four weeks when the retention apparatus or bed care may be discontinued and the forearm supported in a sling. Non-union is rare. Some deformity at the site of fracture is not unusual but this in no way interferes with function of the extremity.

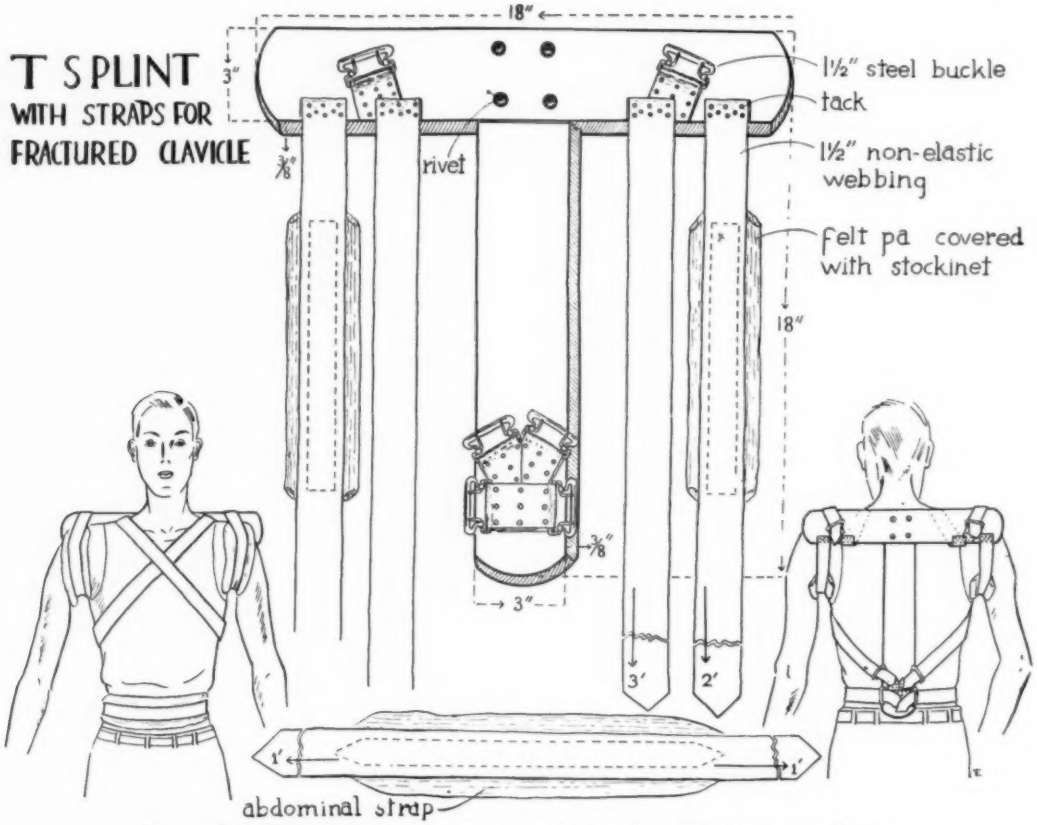


FIG. 3. The T-splint, showing construction and application to patient.

FRACTURES OF THE SCAPULA AND RIBS*

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FRACTURES of the scapula and ribs may be considered in a group because of their adjacent location, similar etiology and somewhat similar treatment. Fractured ribs are, of course, much more common than fractured scapulae, primarily because there are twenty-four ribs and only two scapulae. This ratio of 12 to 1 is approximated in our series of 551 rib fractures and 37 scapulae in a proportion of 14.8 to 1. The proportionate excess of ribs is due to easier accessibility of the ribs to trauma. All the cases in this study were treated as in-patients at the Beekman Street Hospital for the ten year period of 1926 to 1935 inclusive.

THIRTY-SEVEN FRACTURES OF THE SCAPULA

Age: Youngest, 8, oldest, 77; average, 41.7 years.

Sex: Male, 36; female, 1

Occupation:

	Cases	Per Cent
Hazardous	18	48
Moderately hazardous	11	29
Sedentary	6	20
Unknown	1	3

Nature of trauma:

	Cases	Per Cent
Falling injury	21	57
Direct blow	12	32
Crushing injury	4	11

Twenty-five of the thirty-seven cases, or 67 per cent, had associated fractures or dislocations, nearly all of the bones of the body being involved. Ribs were most commonly fractured with the scapula, there being twenty cases, or 54 per cent. The skull was the next most common with ten cases.

Other associated injuries, besides the fractured scapula and other fractures and dislocations, were common. Thirty out of the thirty-seven had other definite injuries, such as lacerations, contusions, abrasions, concussion, shock, etc.

Symptoms and Signs: Pain in the shoulder, limitation of motion and tenderness over the scapula were the most commonly noted symptoms and signs. Most of the cases were in slight shock.

Hospital Morbidity: Lowest, one day; highest sixty-one days. Total for the thirty-seven cases was 582 days, with an average of 16 days.

Mortality: four out of the thirty-seven cases died, or 10.8 per cent. The cause of death was multiple injuries in all including fractured skulls in three instances.

LOCATION OF FRACTURES

(Some of the scapulae were fractured in more than one location.)

Body	29
Acromion	4
Glenoid	7
Spine	2
Neck	2
Coracoid process	2

In 16 fractures, or 43 per cent, there was displacement of fragments by *x*-ray findings, and in twenty-one, or 57 per cent, there was no displacement.

Treatment: The cases averaged fifteen days in bed. In five, rest in bed was the only treatment. Most of them received physical therapy, usually in the form of early radiant light and light massage, then active motion of the shoulder after the first week. In only one case was open operation done, and this was unsuccessful.

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Several had slings, two had Velpeau bandage, two had Sayre Adhesive dressing and in three, traction suspension to the upper extremity was used. These cases were: (1) fracture of the spine, acromion and glenoid with displaced fragments; (2) a fracture of the body of the scapula with an associated fractured humerus; (3) following operative removal of a fractured coracoid process.

Final Results: Twenty-one cases could not be traced. Of the known results, which were sixteen, four died, eight were good results, three fair and one poor.

As can be seen from the foregoing data, fractures of the scapula usually occur in the hazardously occupied male laborer in his early forties by a severe form of trauma which also results in many associated injuries. Very little difficulty is experienced in diagnosis, as there is usually pain and limitation of motion in the shoulder and tenderness over the scapula. An important observation is that the first *x*-ray of the injured region may be negative for fracture as it is usually also taken for ribs, but not infrequently subsequent *x*-rays centered on the scapula will show a fracture.

The high morbidity and the mortality is due to associated injuries, a fact which also prevents a very clear conception of the treatment of the fractured scapula.

From experience and from various opinions in the literature, including the author's previous article on the subject[1] we are able to advocate certain principles in the treatment of various fractures of the scapula.

Fractures of the Body: Incomplete. Ambulatory, sling and physical therapy consisting of heat, massage, active and passive motion every second day, beginning after three days and lasting from two to three weeks, after which time sling can be discontinued.

Fractures of the Body: Complete. Whether fragments are displaced or not, flat on back in bed with immobilization of shoulder and arm by a Velpeau bandage. After ten days patient to be allowed out of bed, arm placed in sling, discharged from hospital and given physical therapy as above for three or four weeks, making a total of about five weeks' treatment.

Fractures of the Neck: Scudder[2] advocates traction abduction of the extremity with the patient in bed. Cotton and Brickley[3] advocate a manipulative procedure for reduction, while Hitzrot and Bolling,[4] in reporting eight cases, stated that manipulation or traction had no effect on the lesion and all were abandoned for a Velpeau bandage. They state also that massage, baking, and careful attention to the after-treatment will give practically perfect functional results—that the resulting function is so satisfactory that ill-advised attempts at correction are to be condemned. Should a type of fracture occur in which the displacement actually promised a bad functional result, the fracture line could be best approached from behind and the glenoid fragment pried into position in this way with correction of the coincident injuries by appropriate methods (repair of ligaments, etc.). We have tried no manual manipulations and advocate a Velpeau bandage and physical therapy.

Fractures of the Acromial Process: Scudder[2] states that there is difficulty in maintaining reduction by any apparatus. He flexes the forearm, lifts the arm upward, and applies counter pressure on the inner fragment, followed by a heavy bandage, and states that union will occur in three to four weeks. We concur with this procedure.

Fractures of the Glenoid: The following suggestions are offered. Bearing in mind that these fractures are into the shoulder-joint, early motion is important unless there is so much separation of fragments as to move the fragments when the arm and shoulder are moved. Thus, if there is great separation, these should be treated by immobilization for three weeks in a Velpeau bandage with the patient in bed, followed by sling and physical therapy, consisting of heat, massage and active motion. If there is not great separation, put the patient in bed with no further immobilization

for three days, and then allow him to get up, with the arm in a sling, to be discharged from the hospital, and to receive daily physical therapy consisting of heat, massage and active motion.

Fractures of the Coracoid Process: Conservative treatment is advisable.

As mentioned previously, the cases of this series were all hospital in-patients, principally because of multiple injuries. There is no reason why most of these fractures could not be treated in the home by the surgeon or general practitioner as long as an accurate diagnosis has been made and the case is not complicated.

ONE HUNDRED SIXTY-THREE CASES OF FRACTURED RIBS IN THE SAME TEN YEAR PERIOD

In the 163 cases there were a total of 551 fractured ribs ranging between one and fifteen ribs per patient, with an average of three and a third. The most frequent ribs to be broken were the 5th, 7th and 8th, with seventy-one fractures for the 5th and 8th each and seventy fractures for the 7th. The 1st and 12th ribs were least frequent with only twelve of the 1st and eleven of the 12th. This is due to the protection of the 1st rib by the clavicle and the flexibility of the 12th rib.

Age: Youngest, 5; oldest, 77; average, 45.4 years.

Sex: Male, 148; female, 15.

Occupation:

	Cases	Per Cent
Hazardous	98	60
Moderately hazardous	37	22
Sedentary	14	8.5
Unknown	14	8.5

Nature of Trauma:

	Cases	Per Cent
Falling injury	66	40.7
Direct blow	65	40
Crushing injury	29	17
Other	2	1.2

Eighty-eight of the 163 cases, or 54 per cent, had other fractures or dislocations.

One hundred twenty-three cases, or 76 per cent, had other associated injuries beside fractures and dislocations.

Symptoms and signs: Nearly all of the patients complained of localized pain in the chest, the pain being accentuated by inspiration. Respiratory difficulties, including cough, were common. Only the more severely injured were in shock.

Hospital morbidity: Lowest, one day, highest, 127 days. Total for 163 cases was 2740 days, with an average of 16.8 days.

Mortality: Forty died, or 24.5 per cent mortality. Twenty-nine of the forty fatal cases had other fractures or dislocations: thirty-eight had associated injuries other than fractures. Twenty-five of the deaths occurred on the day of admission. The average morbidity of the fatal cases was three days. The first diagnosis mentioned in the cause of death was shock in twenty-three, multiple injuries in six, and cardiac death in three. Causes of death relating primarily to the lung were specified as: lacerated lung, five cases; pneumonia, two; asthma, one; relating to the pleura: hemothorax, six cases; hemo-pneumothorax, six cases. Other diagnoses mentioned as cause of death were: ruptured spleen in two cases, ruptured liver in two, and retroperitoneal hemorrhage in one.

LOCATION OF FRACTURES

	Cases	Per Cent
Posterior	53	31
Axillary	71	41
Anterior	21	12
General	24	14
Unknown	2	1

Displacement of fragments was noted either clinically or by *x*-ray in eighty-one cases, or 49 per cent.

Type of Fractures: In 114 cases, or 70 per cent, the fractures were simple and in 49 cases, or 30 per cent, the fractures were in some way complicated—41 of these, or 25 per cent, being compound either externally or internally.

Treatment: Most of the chests were strapped with adhesive. A body binder and sling, or sling alone, was used in a few cases. The cases with multiple severe injuries were treated primarily for shock. Physical therapy was employed, usually

just in the form of heat. Patients were kept in bed for a great variation of time depending somewhat upon discomfort in the chest, but usually depending upon chest complications or associated injuries.

Final Results: The results in seventy-two cases, or 43 per cent, are known. Forty died, twenty-five patients had good results, while seven were known to have had persistent symptoms recorded as follows: persistent pain in four, slight pain on cough and sneezing in one, pain on deep breathing in one and occasional pain, one.

COMPLICATIONS

We have deferred this subject until the last as herein are the real problems in dealing with fractured ribs. A simple fracture of one or two ribs without complications or other injuries may be handled successfully by physicians in general without special training, usually without hospitalization. After an injury to the chest when there is local pain and local tenderness over a rib or ribs it is usually advisable to have an *x*-ray taken. Sometimes this is not practicable and if the physician can make the clinical diagnosis of a bruised or fractured rib with no evidence of displacement of fragments or pleural or lung injury, I believe he is justified in foregoing the *x*-ray because the treatment would not be altered by having the picture. However, whenever there is any possible question of insurance or other compensation or litigation, the *x*-ray should never be neglected as it is necessary as a matter of record, also to protect the physician. It is essential that the chest should be properly and adequately strapped. Although a simple procedure, we will outline a definite technique for the uncomplicated case.

TECHNIQUE OF CHEST STRAPPING

Carefully shave the area to be strapped, and apply ether to the skin. The area to be strapped should extend to at least two ribs above and two ribs below the fractured rib or ribs and in circumference should extend from the nipple line on the unaffected side across the affected region to the mid-scapular line of the unaffected side. In other words, three-fourths of the entire chest in circumference is strapped. The width of the adhesive is usually 3 inches, depending upon the size of the patient. It is advisable to measure and cut the desired amount of adhesive before applying any. With the patient standing erect, with heels together, with both arms extended to 90 degrees from the side, the uppermost strip of adhesive is anchored at the nipple line on the unaffected side, the patient is asked to inhale as fully as possible, then to exhale and hold it. During this period when the lungs are as nearly collapsed as possible, the adhesive is carried around the chest firmly. This is repeated for as many strips of adhesive as is necessary, each strip of adhesive overlapping the adjacent one by one half. A small vertical strip of adhesive is applied to the ends both anteriorly and posteriorly to prevent them from slipping. A strapping may be reinforced in two or three days over the original strapping and should be removed for the protection of the skin and reapplied in from five to ten days, depending on the temperature and activity of the patient. Water-proof adhesive may be used, allowing the patient to take a shower bath.

LIST OF COMPLICATIONS

Those applying particularly to the lungs were: laceration of lung in seven cases, some of these being designated as crushed chest; pneumonia following trauma to the lung in one, and asthma in one.

The complications referring particularly to the pleura were: superficial emphysema of the chest wall in fourteen cases, which means there must have been a laceration of the pleura with some degree of pneumothorax, the air escaping to beneath the skin; hemothorax in nine cases, and hemopneumothorax in eight cases. The blood from the chest was removed by aspiration in only one case. Complications other than of the lung or pleura were:

severe shock in seventeen cases; ruptured liver in two; ruptured spleen in two; contusion of the kidney in two; cardiac disease in three; retroperitoneal hemorrhage in one, and multiple internal injuries in one.

FRACTURED RIBS WITH HEMORRHAGE INTO THE CHEST

This is our most serious problem in the treatment of fractured ribs. The handling of this type of case requires considerable experience in traumatic surgery and should not be attempted alone by the general practitioner or inexperienced surgeon. We have never had any trouble with cases of simple pneumothorax with superficial emphysema of the chest wall. These cases should be left alone; the affected side of the chest kept firmly strapped and the patient kept in bed until evidence of pneumothorax has disappeared. Then allow him up gradually, watching for return of pneumothorax.

The hemothorax or hemopneumothorax is not as simple. Let us visualize what happens in a crushing injury of the chest. The jagged ends of broken ribs pierce through both layers of the pleura and into the substance of the lung. Blood and air pour out from the lung into the pleural cavity, thus expanding the latter. The pleural cavity, now, instead of merely being a potential cavity, is possibly inches in width and the entire length of the chest in height, filled with blood and air or blood alone. This pushes the injured lung centrally, compressing it and usually stopping the hemorrhage from the lacerated lung. The blood and air in the pleural cavity are thus acting as a splint to the injured lung and tend to keep the entire side of the chest immobile. This splinting action is to be desired because it helps to heal the injured lung by direct pressure, and in immobilizing the chest it helps to heal the injured chest wall. But what about the blood and air in the pleura? Are they doing any harm? They have been exposed to infection either from the lung or from the outside or both. Should we leave a potentially infected fluid in the chest, running a risk of fatal empyema? From our experience the answer is yes—be conservative—let the fluid alone.

It will be noted from the foregoing, in our cases of hemorrhage, that only one was aspirated. This was because of respiratory embarrassment. What happens if we do leave this fluid and air in the pleural cavity? It becomes thick and semi-clotted and the lung gradually pushes from within outward as it expands. At the same time the blood and air are gradually being absorbed. During this time the patient will run a persistent elevation of temperature but will not look particularly sick. This persistent elevation of temperature, ranging around 101 and 102 degrees Fahrenheit, may continue for weeks and should not unduly alarm the surgeon. During these weeks of gradual absorption of blood, which causes the temperature, and gradual expansion of the lung, the surgeon will probably be tempted to insert a needle and see what the fluid looks like. This temptation should be overcome. If the blood is removed the lung will probably hemorrhage again and the situation will become worse, or if there is a very low grade infection which nature is taking care of, an aspiration may flare it up. We believe, however, that there are two indications for the removal of part or all of the bloody fluid in the pleural cavity:

1. Severe respiratory embarrassment which can not be relieved by chest strapping, the administration of oxygen or other means.

2. The rise of the temperature curve, after a period of time when the temperature has ranged rather steadily around 101 or 102, it starts to spike to 104 or 105 degrees and continues spiking with the patient obviously becoming much sicker. This would indicate the probable presence of empyema and should be treated accordingly.

It may be that in the future fresh cases of hemothorax will be completely aspirated immediately and sterile air replaced in the pleural cavity to act as the internal splint, the air being gradually absorbed. This

would eliminate a long dangerous period of fever with the gradual absorption of the potentially infected blood. We cannot advocate this, however, as we have not tried it.

In fractures of both the scapula and ribs we wish to stress the importance of conservative treatment, particularly where hemorrhage in the chest is involved.

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"Another type of fracture occurring in osteomyelitis is a fracture through the dense, eburnated bone. This bone is extremely hard and capable of sustaining great pressure, but it is brittle, and as a result may be broken by relatively slight force."

"Any compound fracture may be contaminated with tetanus, and this is much more easily prevented than cured. Consequently, antitetanic serum (1,500 U.S.A. units) should be given subcutaneously and recorded immediately after admission [to the hospital]; otherwise in the press of duties incident to treating the fracture it may be forgotten."

FRACTURES OF THE UPPER END AND SHAFT OF THE HUMERUS

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THIS article, a part of a collection dealing with fractures, is necessarily restricted to pertinent facts relating to the immediate subject. However, to emphasize certain things, I will have to trespass on the subject matter in other papers of this issue.

To assume the responsibility of treating an injury or fracture near the shoulder requires a degree of coordinated knowledge of anatomy, physiology, pathology, and simple mechanics with an experience in the application of these fundamentals.

For one to accept this responsibility without possession of the above, is one of the surest ways in surgery of bringing to the one doing so, a degree of worry not commensurate with the reward. However, this does not preclude the application of first aid methods by those properly qualified, for the transportation of these cases.

Prolonged disability of the shoulder joint frequently follows what the patient and physician consider to be a minor injury which shows no *x*-ray findings to suggest treatment. The treatment in such cases, however, should be determined by the subjective symptoms of the patient, manifested usually by pain and protective spasm, which are worse at night and made more comfortable by the erect position. These symptoms can and should be relieved by a dressing to be described later in this paper, until all pain of movement has subsided. (See Figures 1, 2, 3.)

The laity can understand that a bad fracture of the upper end of the humerus may leave a certain degree of disability as an end-result with which they are contented, unless it be of compensation or legal importance. Under such circumstances, unless the medical attendant has thoroughly convinced the patient of his understanding of the lesion and its treatment, the patient is apt to manifest obvious discontent with the prolonged convalescence.

The shoulder injury which happens to be overshadowed by others more immediate and important at the time the injured comes under treatment, may be the sole remaining and disabling lesion left to harass the doctor. Therefore, after treating the major injuries be sure that early treatment is given to what appears to be minor at the time, but is of serious importance if the arm, later in convalescence, becomes weight-bearing in the use of crutches.

Every fracture should be treated as an acute emergency requiring immediate treatment. It is not necessary to wait for the *x*-ray findings to institute the same.

Roentgenology is a comparatively recent adjunct to the treatment of fractures, and has taught us the pathological details of the classical and atypical bone injuries which were formerly not known to the degree they are today. This should enable us to render better first aid, and in some cases early reduction; but too often one finds that dependence on *x*-ray findings for a diagnosis delays treatment indicated by the most obvious clinical evidence. Fractures were treated before the *x*-ray was discovered. Delay in obtaining one should not preclude the early institution of proper treatment. An *x*-ray is imperative. It is of greater value to show the good results of early treatment than to reveal the complications of delayed treatment.

The surgeon who considers himself most competent to operate for the result of delay in treatment, too frequently will be found lacking in his knowledge of first aid, or intolerant of its application by those trained in it.

To fulfill these requirements, one should be in a position to treat the case as such at a moments notice, either in or outside a hospital.

Every person suffering a fracture has a degree of shock proportionate to the site, character, and the number of lesions. The problem presents a human being in shock. There is damage to soft tissues and an internal hemorrhage due to a broken bone. A fracture is an acute emergency, because there is a broken bone surrounded by an internal hemorrhage which is increasing the difficulty of reduction if displacement exists. If there is no displacement of the fragments, a dressing is necessary to prevent this being produced by movement and muscle spasm. If displacement exists, the hemorrhage is gradually adding to the pressure inside the injured tissues by reason of such displacement, and is distending the traumatized tissues about the fracture with an enlarging blood clot. The venous and lymphatic return are interfered with, causing swelling. The fascial muscle compartments are filling with edema and hemorrhage, thereby shortening these spaces and the muscles they contain. This prevents the muscles elongating to permit reduction. Pain is due to displacement and muscle spasm, and any movement of the limb produces more muscle spasm and greater displacement. The longer these factors exist before reduction, the more difficult it will be and the less apt one is to secure a satisfactory replacement of the fragments by any procedure. I believe that a lack of adequate appreciation by doctors of the strength of muscle resistance manifested in its normal and pathological physiology, is one of the large factors in our present day fracture problem.

To treat a fracture, one must treat the soft parts: to treat the soft parts, one must treat the fracture without injury to the soft parts and do so quickly.

A doctor or surgeon treating fractures should have two fracture bags. He should have a small bag containing the following for first aid for the upper limb:

Basswood splints,
Cotton,
Adhesive plaster (zinc oxide),
Assorted safety pins,
2–3″ muslin bandages,
2–6″ muslin bandages,
2–3″ gauze bandages,
2–2″ gauze bandages,
Alcohol,
Iodine 3½ per cent,
Wooden tongue depressors,
Sterile dressing set and dressings,
Hypodermic and morphine.

A second large bag is necessary, with equipment to supplement the first bag together with separate splints suitable and adequate to establish transportation traction for upper and lower limbs, or, when the case cannot be taken to a hospital, enough supplies to complete a balanced traction for either limb in the patient's home. This bag should contain the following:

3–6″, 3–4″, and 3–3″ muslin bandages,
3–3″, 2–2″ gauze bandages,
4–4″ and 3–3″ Plaster of Paris bandages,
1 dozen large, medium, and small safety pins,
Sheet wadding heavy and light,
1 roll cotton,
Stockinette —6″ and 3″ width,
1 roll zinc oxide adhesive plaster 3″ × 5 yards,
6 swivel pulleys,
1 hank small traction cord,
1 yard Silence cloth for hammock slings for Thomas splint,
Weight bags,
Buckles,
Brass S hooks,
Orthopedic webbing,
Splintwood,
1 can Ambroid canoe glue,
1 sterile dressing set and dressings,
Tr. iodine 3½ per cent
Alcohol,
Aristol powder,
Talcum powder,
Large paper clips,
Apron and rubber gloves,
Plaster knife and sharpening stone,
Small pocket kit of tools,

A surgeon who is not ingenious enough to construct a makeshift for an overhead suspension when needed should have his own frame, or send for the surgeon who has one of these requisites. One cannot depend upon surgical supply houses to meet the deficiency created by the doctor's

oversight. With this equipment there can be no excuse for delay, either in or outside a hospital. The standards for hospital fracture equipment are in print, but too frequently the materials listed are not immediately available in hospitals.

For highway accidents the American Red Cross has equipped highway First Aid Stations with transportation splints. These are available to the doctors of this country for use in such injuries together with a personnel trained in first aid to assist the doctor. This valuable service should be used to prevent displacement and help minimize shock in moving these injured cases to hospitals so that the treatment of their fractures will not be delayed on reaching there.

The history of the degree and character of the mechanism which produced the injury is important to record, as it furnishes valuable information to the surgeon.

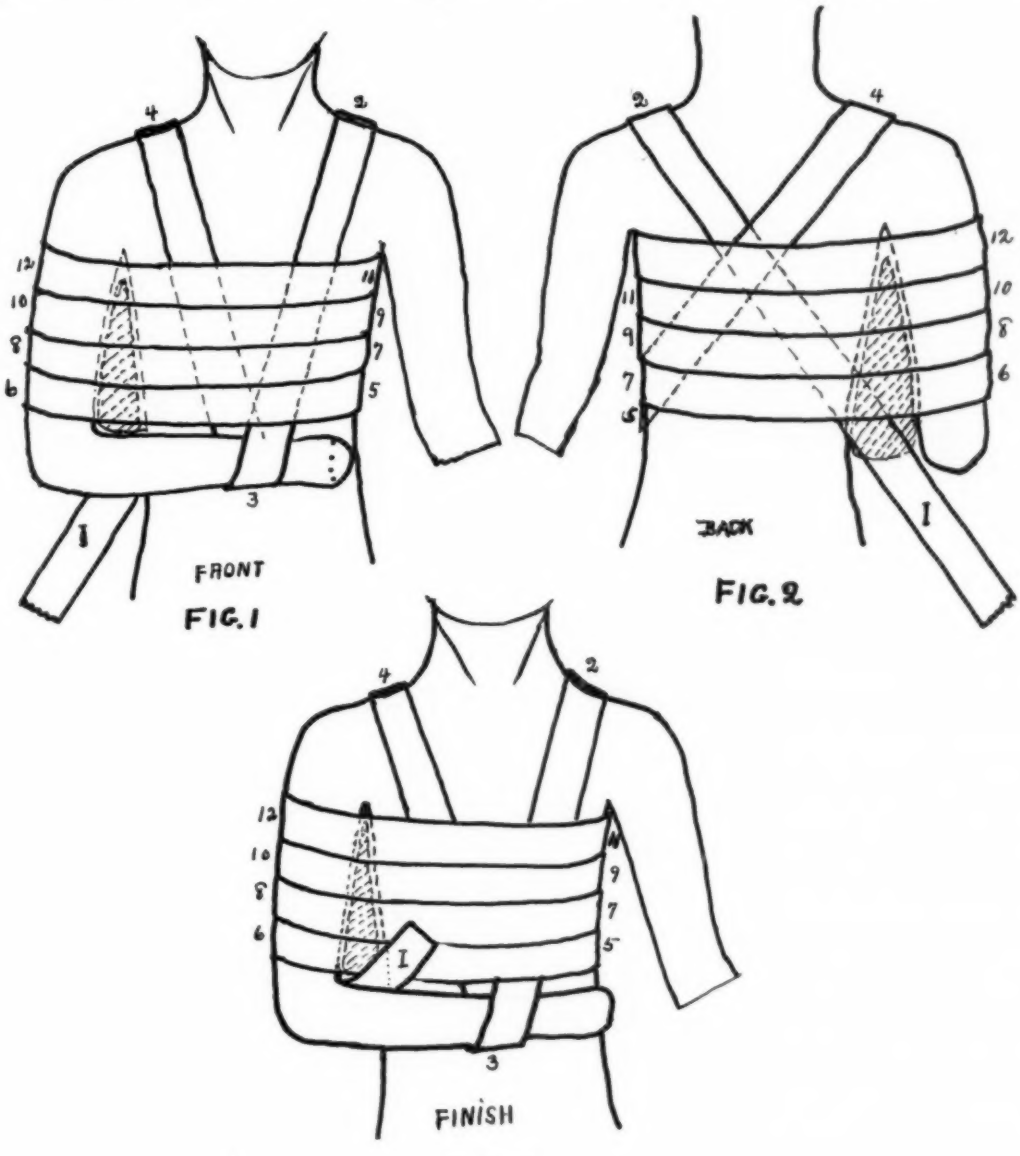

FIG. 1

FIG. 2

FIG. 3

FIGS. 1, 2 AND 3. Axillary pad, sling and swathe made with one 10 yard, 4 inch muslin bandage. The serial numbers from 1 on show the sequence of application. A safety pin is placed to include the innermost layer at each exposed angle. For first aid this is not required. A small rope may take the place of a bandage.

A patient subjected to a severe injury as a fall or an automobile accident is usually in shock, and should be suspected,

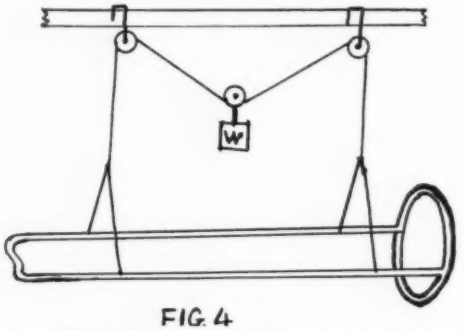

FIG. 4

FIG. 4. Method of suspending arm splint for supporting upper limb with forearm extended.

especially if unconscious, of possibly having sustained more important injuries of head, spine, pelvis, and lower limbs. If the patient is resting in a hazardous position, these major injuries should be given precedence in their care by using suitable methods before moving the patient to a place of safety or transporting him. A cursory examination of the limbs will reveal adequate indications for splinting for transportation to prevent increasing shock in moving, and this will not conflict with caring for the major lesions.

A temporary fixation of obvious fractures of the upper humerus can be easily accomplished by means of a sling, axillary pad, and swathe. (Figs. 1, 2, 3.) The pad can be made by using some piece of clothing. Where fractures about the elbow and forearm exist on the same limb, a right angled splint can be made by strapping together the ends of two basswood splints with adhesive plaster, and a thick layer of cotton laid on the splint. The limb is then laid on this cotton-covered splint with another layer of cotton covering the limb and the bandage applied. A splint which has the padding bandaged to it presents a convex surface to the convex surface of the limb. This exerts pressure on the muscles and prevents stabilization by its curved cross section. Do not apply adhesive plaster around a limb to stabilize such a splint: when it is removed it may cause a bleb, and a bleb once formed affords many contraindications for any necessary operative procedure by reason of its harboring infection, as well as preventing the application of skin or skeletal traction where these might be needed. This splint with a long arm portion reaching to the shoulder can be applied externally or internally, and can be used with a bandage sling, axillary pad of clothing or cotton, and a swathe to stabilize a fracture of shoulder, elbow, and forearm provided traction is not indicated.

Where extensive comminution, compounding, over-riding, or persistent displacement of the upper humerus exists, traction should be instituted. A Murray-Jones hinged ring arm splint is applied while manual traction is being made on the wrist by a bystander. The bars of the splint should be in the saggital plane to permit adduction of the limb to the side of the body for transportation on a stretcher. If applied as on the lower limb, adduction is not attained without undue pressure in the axilla by the ring. The wrist is then encompassed with voluminous soft clothing or cotton. One end of a piece of bandage or rope is tied in a loose loop with a square knot about the upper portion of the wrist padding. One strip is placed on the flexor surface and another on the dorsal surface of the wrist. The free ends of these are then passed in front and back of the hand, and tied over the end bar of the splint. A piece of stick longer than the space between the bars where it is to rest is introduced between the traction strands. Twisting the stick shortens the traction strands, takes up the slack, and replaces the manual traction maintained until this is accomplished. The end of the stick is caught under the side bars of the splint and fastened with adhesive plaster.[1] A muslin bandage is then tied to the uppermost bar near the axilla, passed alternately, first under the arm and back to the uppermost bar, next around both bars and the arm. One suspends and supports the limb from the uppermost or anterior bar while

the next turn prevents side swing. This is continued down to the wrist. The circulation and sensation of the hand have to be watched, and the traction should be released every twenty minutes, during which period traction by hand is maintained. Adjustment of the traction loops should be done frequently enough to avoid pressure on nerve, vascular supply, and necrosis of superficial tissues—just enough traction should be used to prevent further displacement of the fragments. With too much traction, the ring in the axilla may exert pressure on the axillary artery, vein, and brachial plexus, thus producing severe and serious complications.

If the fracture is compounded or projecting fragments are present, iodine 3½ per cent should be applied to the exposed tissues and wound, and a sterile pad with a bandage applied. Judgment is necessary regarding the type and degree of compression bandage to be used in controlling hemorrhage in this region. If a tourniquet is indicated, use it, but follow the rules for tourniquets, and do not cause hemorrhage or damage with it.

If, when traction has been applied, projecting fragments are drawn into the soft parts, even though they have been treated with iodine, they have drawn infection deeply into the wound. The person observing this take place should be sure this data accompanies the patient to the surgeon, who shall immediately débride and cleanse the infected area under an anesthetic when the case reaches the hospital.

On reaching the hospital, shock treatment is instituted as may be indicated. The arm in traction can be slowly abducted to a comfortable degree and the end of the splint supported in an elevated position to combat swelling of the hand and limb.

The ambulatory patient should be placed on a table or bed for examination, lest he become faint, nauseated, or by weakness fall from a chair and receive further injury. The clinical examination then can be carried out safely and if done gently will permit morphine or other sedatives to become active. Note the position the arm occupies and how the patient holds it.

As soon as shock permits, the scapular

Fig. 5. Front of elephant head plaster case with ambulatory traction on arm for day use. (From Gordon in *J. A. M. A.*, vol. 96, 1931.)

bony landmarks are inspected for abrasions or contusions, and palpated for tender areas, or bone irregularity. Are the spine, borders and angles of the scapula intact? Are the acromion, acromio-clavicular joint and clavicle negative? Is the shoulder just below the acromion process flattened as compared with the normal one? Is this due to old paralysis or recent injury, i.e., dislocation of the humeral head, or fracture of the anatomical neck with displacement of the head? Is the greater tuberosity tender? Is this tenderness due to a traumatic bursitis or a contusion which will develop the former, or does it represent the direct point of tenderness of a fracture line? Can the lesser tuberosity be felt? What is the relation of the humeral head to the acromion? Is it the same as on the normal side, and if not, why? Is the surgical neck tender? If swelling precludes easy

determination of these points as an indication of bone injury, palpate with the fingers along the upper half of the humerus

Fig. 6. Back of Figure 5. (From Gordon in *J. A. M. A.*, vol. 96, 1931.)

from below upward and above downward, note if and where there is an area of tenderness, i.e., direct tenderness or pain. Then gently rotate the arm a few degrees with the forearm flexed holding the elbow in the palm of your hand, the fingers of the other hand placed on the humeral head and coracoid process of the scapula. Does this cause pain, i.e., indirect near any of the points of direct tenderness? If it does, suspect a fracture at that point. If the head rotates with the shaft there may be an impacted fracture of the surgical neck. If the head does not rotate, and there is a suggestion of crepitus, stop—a clinical diagnosis of fracture has been made which is not firmly impacted, or it may be comminuted. A temporary fixation dressing with or without traction should be applied before the details are sought for by immediate *x*-ray. Crepitus is not necessary to diagnose a fracture, but if elicited in a gentle examination it is a pathognomonic sign. If these signs are indefinite and insufficient to make a diagnosis of fracture, the upper arm and shoulder joint are examined for functional integrity. Have the patient perform abduction, elevation upward and forward, external and internal rotation, and note what he cannot do. If this suggests nothing, gently resist these same voluntary movements and determine what motion is painful. This may point to evulsion of a muscle insertion, a reduced dislocation, or tendon rupture by reason of inability to perform against resistance, the work a muscle group should accomplish. Note what positions cannot be maintained against gravity or pain and remember that pain causes reflex loss of function as well as spasm or evulsion of tendons. Note the degree of swelling, determine the reflex loss of function, and if it is due to spasm or evulsion of tendons. Note the degree of swelling, and determine the vascular integrity of the whole limb. Is there a relation between the swelling and absence of pulse? Examine for anesthesia and loss of motor function in the muscles which cannot be activated—what nerve is involved and where? Coordinate the points of direct and indirect pain and tenderness thus obtained with the classical bone lesions which occur in the upper humerus and about the shoulder joint. Do the same with the symptoms of injury in the soft tissues and functional loss found by the examination. Do they appear to be correlated or is the bone intact with soft tissue injury only? One can then form a fair picture of the nature and degree of the injury to bone and soft tissues.

At this time the *x*-ray shows the bone damage and is prone to attract and concentrate attention to this alone, and affords little except indirect evidence of damaged, or intact muscles, or soft tissue interposition. It is only by means of the clinical examination that the condition of the soft tissues can be determined.

The novice is prone to look at the film of a bone lesion and feel that if this and that is done, reduction will take place.

However, this and that cannot be done unless the pathology in the soft tissues permit, and they must be given every consideration based on a thorough understanding of their normal and pathological physiology in reducing a fracture, maintaining it, and restoring function to the limb. This data taken to the roentgenologist and discussed with him over the films makes for better clinical results, more accurate and quicker reports, economy in films, and improvement in diagnostic acumen.

By efficient first aid, we have prevented whatever type of fracture exists from becoming worse, spasm and shock have not been increased, and possibly improved.

It becomes one's duty to determine from the examination of the *x*-ray films the details of the problem presented by the bone injury for further treatment. One or more of the following may be found:

1. Dislocation of the head of the humerus,
2. Fracture of the anatomical neck;
   a. Without displacement of the head,
   b. With displacement of the head—head may be out of capsule,
   c. With rotation of the head—head may be out of capsule.
3. Transverse fracture through the surgical neck;
   a. Without displacement or impaction,
   b. With moderate displacement but impacted,
   c. With complete displacement, overriding,
   d. With distal fragment displaced medially,
   e. With distal fragment displaced laterally,
   f. Oblique or spiral.
4. a. Comminuted without much displacement of one or more fragments,
   b. Extensively comminuted with marked displacement of one or more fragments and extending through the entire upper end of humerus.
5. Fracture of the greater tuberosity alone;
   a. Without much displacement,

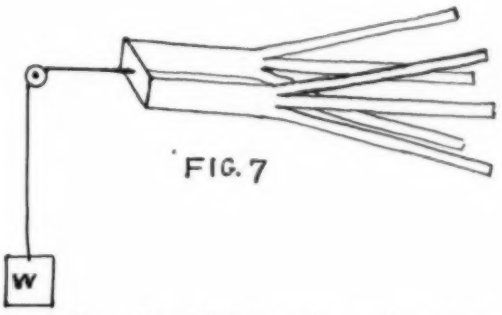

FIG. 7

FIG. 7. Spreader with three strip traction straps, rope, pulley and weight, to be used with Thomas splint. The pulley is attached to the frame and not to the splint.

   b. With much displacement,
6. In childhood;
   a. Epiphyseal separation with displacement,
   b. Pathological—through bone cyst or tumor.
7. Complicating lesions of associated bones;
   a. Fracture of acromion of scapula, glenoid, or neck,
   b. Fracture of clavicle or acromioclavicular dislocation.

The condition of the soft tissues being known, the decision as to the next procedures can be roughly determined from the film, which will show the kind of fracture and the degree of displacement, afford an idea of the direction and degree of mechanical force which will be called for in reduction, and suggest the measures required for retention. These tentatively will be as follows:

If the fracture is compound, it will have to be thoroughly débrided and left open. When this is done, an open replacement may sometimes be accomplished at the same time. If reduction can be accomplished while débriding the wound, one will have to decide whether an internal fixation device will be required or permitted by the infection which will take place. The upper end of the humerus is a bad place to have infection, and it is better to depend

on external retention with only moderate reduction than good replacement with internal fixation followed by infection and

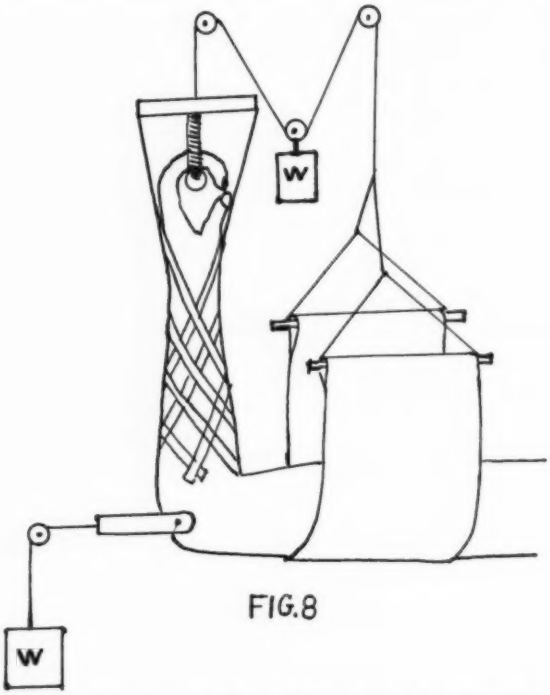

FIG.8

Fig. 8. Arrangement for skeletal traction wire with traction device in olecranon.

a "frozen" shoulder or worse. Therefore, it is well to banish all thoughts of internal fixation of a compound fracture of this region, especially by one who feels he is incapable of retaining it by external support and traction. The external support should be arranged to permit dressing and Carreling the wound. The device which lends itself best to this is the Murray-Jones hinged ring arm splint, or half, or full ring Thomas as used during the war for compound infected fractures of the upper limb. The splint should be suspended from an overhead frame and should float on balanced pulley suspension with the bars in a horizontal plane to support the limb only. (See diagram, Figure 4.) When traction is required the traction pulley should be extrinsic to the splint to avoid counter pressure against the trunk by the ring, but the ring should be maintained close to the body without pressure to support the upper part of the distal fragment. When powerful skin traction is required, place the forearm extended. This affords a larger available skin area for traction. The normal position of repose of the arm with the patient in bed is parallel to the body, with sufficient elevation to prevent swelling of the hand. This position affords the greatest pull with the least antagonistic muscle action. However, if abduction is indicated, which is infrequent, it can be easily accomplished, but with a less available skin area; or where skeletal traction is necessary, a wire may be placed through the olecranon or high up on the ulna. The forearm will then have to be flexed and suspended by skin traction with a spreader connected to a rope passed through an overhead pulley, and a counter weight added. (Fig. 8.) This of course externally rotates the distal fragment to a degree parallel to the sagittal plane of the body. These are the immediate needs of a compound fracture.

We have spoken of open replacement of a compound fracture requiring débridement. This should not be confused with a deliberate open reduction with replacement and internal fixation and immediate suture of the wound when no compounding exists. This should only be done where closed replacement by other measures cannot be obtained and by a surgeon with a competent organization to do this, and capable of handling infection should such occur.

To anticipate the possibility that manipulation, traction, or other procedures may fail to secure a reduction, and that operation may be necessary later, the intervening time can be well spent in preparing the site of operation to avoid infection.

When the case is first seen, every tiny abrasion should be carefully treated with 5 per cent gentian violet and methylene blue in 70 per cent alcohol to anticipate any possible operative need.

Operation should not be done in the presence of any sloughing abrasion or follicular infection—hence give the skin and any minute abrasions the greatest possible care under all circumstances.

As soon as permitted by the shock and allergic background of the patient, the

compound fracture case should be tested and given tetanus antitoxin, and antigas serum if indicated, with suitable desensitization as required.

The problems presented by the lesions in the above classification may be dealt with as follows:

Dislocation of the head without fracture of the anatomical neck: Should be reduced and immobilized for two weeks to allow healing of the capsular tear to prevent a recurring dislocation later. A dislocation which cannot be reduced by manipulation or traction should be operated upon within as short a time as circumstances permit. At ten days, healing has so progressed as to make reduction very difficult by open operation.

A fracture of the anatomical neck without displacement may complicate a dislocation, and an attempt at a Kocher might readily tear the head off. If gentle traction under an anesthetic will not reduce it, I would suggest an open operation, stabilizing the head to the shaft with a Sherman bone screw or threaded wires until reduction is accomplished. This fixation can be left in place, removed before closing, or later. Prolonged immobilization should be afforded with *x*-ray checking of the calcification changes in the head as for a femoral neck lesion. Time is the only answer to the degree of blood supply, union, or absorption of the head which may occur. With rotation or wide separation of the head, the blood supply of the head will be lost. Although excision of the head usually gives a poor result leaving a flail shoulder, excision is indicated. After operation a position of abduction to ninety degrees with forward position of the flexed forearm should be maintained with a plaster spica for a long time to develop contracture of the abductor muscles. This affords the best position for a permanently disabled shoulder. Open replacement with internal fixation is theoretically contraindicated, because of the lack of blood supply to the head. Rotation inside the capsule without dislocation is a good indication of destroyed blood supply; and though there are reports in the literature of replacement and satisfactory end-results, these must be very rare. It is impossible to lay down any rule for this condition, except excision.

Fig. 9. Ambulatory traction with axillary pad, sling and swathe for daily use. (From Gordon in *Ann. Surg.*, vol. 90, 1929.)

For a transverse fracture of the surgical neck without displacement: Treat the arm at the side with the forearm flexed across front of the body, using axillary pad, sling, and swathe. If there is danger of displacement, a short internal and long external moulded plaster extending from elbow to and over shoulder tip as a cap can be added inside this dressing. With moderate displacement with impaction, any attempted reduction may lose this position. Therefore leave it alone except to correct marked angulation, and use axillary pad, sling, swathe, with slight ambulatory

traction for muscle spasm and pain when indicated.

For the above with complete displacement: skin with pulley extrinsic to splint. (See Fig. 7.) Where flexion of the forearm is required, skeletal traction with wire in the olecranon will be the more efficient force. (Fig. 8.)

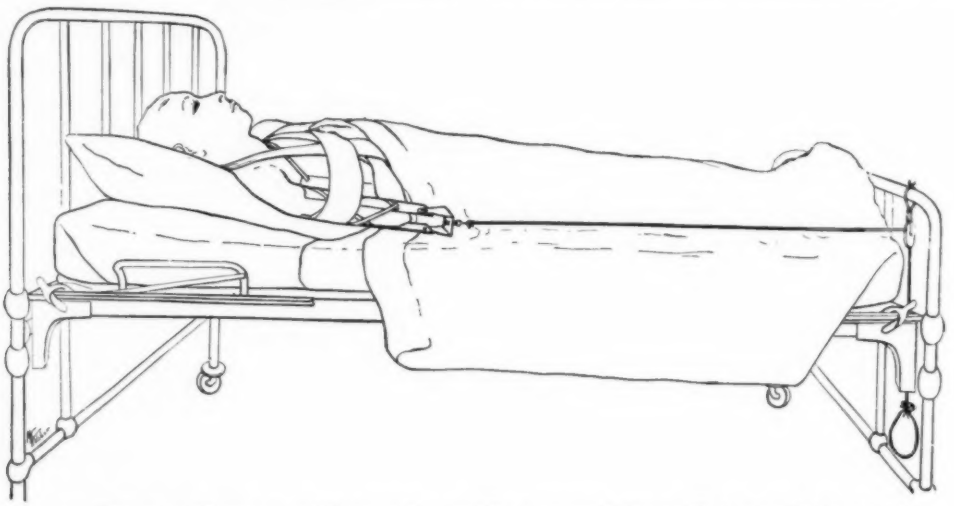

Fig. 10. Same as Figure 9, with traction weight arranged for reclining position at night. (From Gordon in *Ann. Surg.*, vol. 90, 1929.)

Reduction under good anesthesia should be attempted, using traction and manipulation. This should be checked by *x*-ray before and after applying the retention dressing. The position after reduction of the limb is determined by the position in which the reduction can be most easily retained. The dressings used may be the axillary pad, sling, and swathe; plaster spica embracing thorax, trunk and arm, which is imperative in a child and adult where abduction to ninety degrees is required, or the elephant head (Fig. 5–6)—a large shoulder cap of plaster—may be used, when the arm can rest at the side. The old plaster dressings of Stimson do not afford sufficient immobilization. When overriding cannot be overcome and maintained with closed manipulation, powerful traction in bed is indicated. The position of the limb should be parallel to the body toward the foot of the bed, the distal part elevated with forearm extended. This position does not place the pectoral muscles under tension as does the abducted position and gives a more direct pull on the coraco-brachialis, triceps, biceps, and deltoid. The limb should be supported by a ring splint. Traction should be by

These procedures also hold for D.E. F.

Comminuted fractures without displacement as 4-a: Treat with either ambulatory or bed traction (see Figs. 9–10) if indicated, and weights proportionate to whether only muscle spasm is to be overcome, or mushrooming or displacement of fragments to be prevented. Ambulatory traction will pull the head well away from the glenoid, thus demonstrating its efficiency.

With extensive comminution and displacement: If the greater tuberosity retains its position, abduction is not necessary. If it is displaced upward, abduction is indicated with moderate traction, provided the abduction does not displace the proximal end of the distal fragment medially. If this takes place and strong traction will not correct this angulation, a more adducted position even to the side is indicated. The question of open replacement of the separated tuberosity with internal fixation may present itself. Pegs do not hold well where extensive comminution is present. Suturing it in place with chromic catgut, silk, or fine stainless steel wire may be feasible. Where there is extensive frag-

mentation and separation, one has to depend upon traction to improve and maintain the general displacement as best one can. The position used for retention should be determined by an analysis of the fragmentation as a whole, and the one used which will afford the best functional end-result.

A fracture line between the greater tuberosity and the upper end of the humerus, even with slight separation, does not necessarily require an abducted position, as the heavy fibrous investments about this region appear to prevent further separation. However, wide separation calls for the abducted position with external rotation of the flexed forearm held by a plaster dressing. If abduction does not show a satisfactory position in the check *x*-ray film, open replacement with internal fixation by suture or pegging is indicated with the above position and dressing. This lesion is not uncommon with a dislocated shoulder, but fortunately frequently assumes its correct position with reduction of the dislocation, and the arm can be placed at the side with an axillary pad, sling, and swathe.

Epiphyseal separations occurring in childhood: These are difficult to replace, due to inability to control the proximal fragment and especially to retain it through lack of rough engaging surfaces. Every effort should be made at early reduction under an anesthetic by manipulation and traction, using a folded sheet about the body for counter traction. If reduction cannot be accomplished, open replacement is indicated, the greatest care being used to avoid injuring the epiphyseal cartilage or its blood supply. Internal fixation should be avoided if possible. Use a position which will maintain reduction, i.e., abduction in a plaster spica or at the side. Frequent early checking with stereoscopic or lateral films should be done. Traction alone will not do much to replace these lesions as adequate countertraction is difficult. If there is any delay in treatment, they are most difficult to reduce.

Pathological fracture in a child at this point is not uncommon, usually due to a bone cyst. The fracture frequently heals

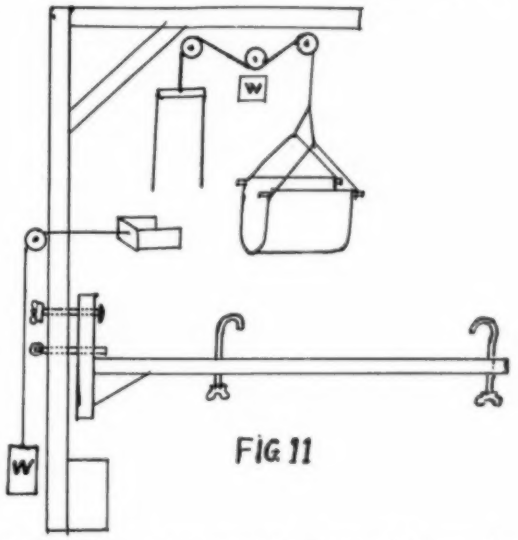

FIG. 11. Arm frame for abduction which can be used with skeletal traction apparatus shown in Figure 8.

the bone cyst and does well. The possibility of malignancy which must be considered can be diagnosed by aspiration biopsy and treated according to the findings.

Complicating fractures of the scapula, glenoid, or neck have to be cared for in a way which will not conflict too much with what one is attempting to do with the upper humeral problem. Maintenance of the normal relationship of the humeral head, scapula, acromion, and glenoid is what is requisite. This can best be accomplished with the patient in bed and skeletal traction through the olecranon with arm abducted and forearm flexed. (Figs. 8–11.) The arm should be kept in this position until union is solid, four to five weeks, and then gradually removed.

Associated fractures of the clavicle can be treated in the same way. Complete acromioclavicular dislocation requires more abduction than the humeral lesion usually permits and will likely have to be operated upon later. Where fracture of the outer end of the clavicle is a complication of acromioclavicular dislocation, a satisfactory result may be obtained.

It is necessary to immediately institute the treatment determined on. Traction which will give excellent results in the first six hours or less, will be of little value in twenty-four. Reduction which could be easily accomplished inside a couple of hours will be impossible in twenty-four. It is this period in fracture treatment which gives birth to more alibis than in any other branch of surgery.

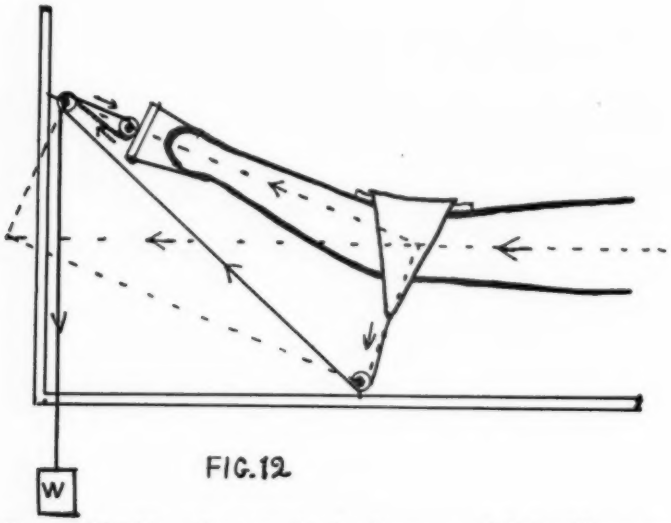

FIG. 12. Double pulley traction for fractures of shaft of humerus as used by L. Blum.

The sling, axillary pad, and swathe can be applied as follows in a few moments for those fractures for which it is adequate. Its application is indicated in the diagrams of Figures 1, 2 and 3.

I have gradually developed this dressing from a bandage sling and have used it for many years. It is excellent for first aid and when properly applied will stay in place a week.

What I refer to as ambulatory traction (Fig. 9) is arranged by attaching adhesive straps to the arm, the lower end of these straps are turned in a couple of times, and a bachelor button is placed in the free end of each. To these are buttoned the ends of pieces of adhesive extending upward from a spreader which supports a weight proportionate to the musculature, i.e., one to three pounds. The axillary pad, sling, and swathe is applied over this. At night the spreader with weights is unbuttoned and replaced by a similar spreader with a loop of wire without weights. (Fig. 10.) In this loop is caught a snap hook on the end of a cord which passes through a pulley on the foot of the bed and is attached to a weight of five to seven pounds. This affords sufficient pull to relieve pain from spasm and to protect against displacement, but will not reduce a marked displacement.

The elephant head case as shown in the picture (Figs. 5, 6) is a large shoulder cap used where there is extensive comminution extending down the shaft for some distance, with a coaptation splint applied to the medial aspect of the arm, and it can be used with the ambulatory traction instead of the axillary pad, sling, and swathe.[2]

Fractures of the shaft involve these same principles except that one has more control of the proximal fragment for reduction and retention.

Shaft fractures fall under this classification:

1. Transverse, without displacement,
2. Transverse with displacement and overriding,
3. Oblique,
4. Comminuted,
5. Spirals.

The method for examination of the shoulder should be carried out and extended to the entire arm.

The symptoms of direct and indirect pain are frankly obvious with false motion. Occasionally the latter is obscure in long spirals.

The first aid for these is the same as for the upper shaft.

The treatment of the compound is the same.

The treatment of the transverse without displacement is with an elephant head case, or arm and body spica. The position should be the one with the least tendency to angulation. If there is 50 per cent engagement, protect against further displacement and angulation, keeping the axes of the fragments parallel.

In any oblique, spiral, or comminuted fracture, traction proportionate to the degree of displacement, muscular volume and quality, and requirements for retention is imperative.

The position of the fracture in the upper, mid, or lower third together with the amount of traction weight required and the condition and tolerance of the soft parts for skin traction determine whether skin or skeletal traction must be used.

With the forearm flexed for a mid or low shaft fracture, the skin does not afford adequate traction surface. When the weight used is too great, blebs form at the upper end by the slipping straps. Skeletal traction with wire in the olecranon is indicated. Do not expect to accomplish traction by a band about the upper part of the forearm flexed to a right angle. This causes pressure, swelling, vascular disturbance, pain, spasm, and accomplishes little.

Where the forearm can be fully extended, skin traction may be quite adequate. The arm should be suspended in some form of splint and extrinsic traction applied as for the upper shaft. (Fig. 4.)

For midshaft, traction as applied to this area by L. Blum,[3] may afford a satisfactory treatment. (See diagram, Fig. 12.)

Abduction is not indicated in the shaft except as required by an associated upper shaft lesion when the latter demands it, and the shaft fracture permits.

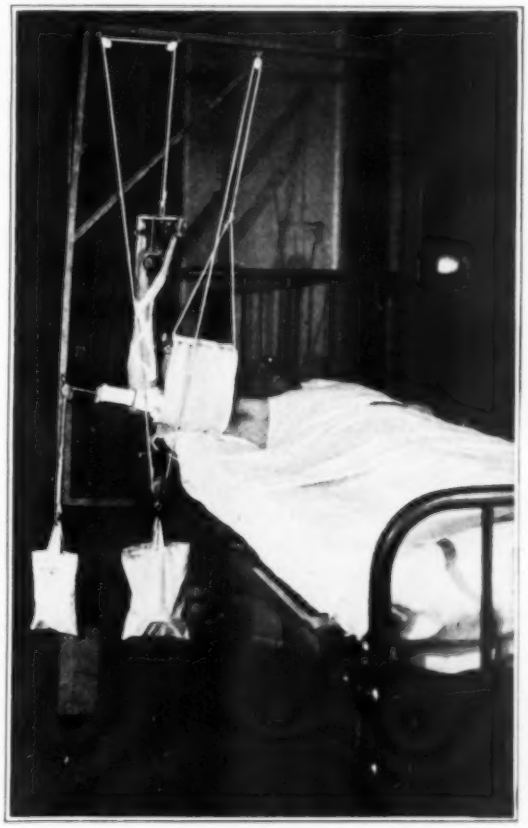

Fig. 13. Abducted position, using arm frame and skin traction when applicable. (From Gordon in *J. A. M. A.*, vol. 96, 1931.)

The simple ambulatory traction with an elephant head case, coaptation splints, or moulded plaster cap will afford a comfortable and satisfactory dressing in comminuted or spirals where moderate traction is required and the patient can be ambulatory.

The transverse with over-riding calls for careful manipulation under anesthesia. If there appear to be dentations which might hold if engaged, a plaster spica about the body, arm, and forearm, can be used as a retention dressing. If reduction cannot be obtained, traction in bed is indicated.

There has developed in recent years the technique of introducing pins and wires traversing the bone and used to obtain re-

duction and retention of the fragments in fractures of the shaft. This has many features to recommend itself to the novice as a solution of his fracture trouble. However, one who has not had adequate experience in the fundamental principles of manipulation, traction, and open reduction, should not adopt this technique as a cure all. This technique should not be learned from an inexperienced high pressure lay instrument salesman, but by watching and studying the problems encountered by the originator of such a technique. These procedures have their place, but not for the inexperienced fracture man.

In all fractures, especially in comminuted and spirals, the position of repose of the proximal fragment is determined by the normal position of repose of the muscles attached to it. Studying the normal arm hanging at the side as one flexes the forearm, it falls across the front of the body. Remember this in controlling the distal fragment in manipulation, retention, and traction, all during recovery. The triceps, coraco-brachialis, and biceps are the muscles which produce over-riding.

This region is famous for nonunion and muscular spiral paralysis. The nerve injury may occur at the primary mechanism and be severed, compressed, or partially lacerated. It may be compressed by the firm late callus formation. Its early integrity should be determined at the first examination before manipulation. The treatment of this injury falls into neurological surgery; but the responsibility for protecting the involved muscles adequately and constantly with a splint, is on the person caring for the case whether this be doctor or nurse, until functional return has been complete.

The problem arises with an immediate lesion as to watchful waiting or immediate operation. With a suitable surgical risk in the presence of an adequate organization for open operation, repair of a fracture and nerve can be done, not otherwise. Better to secure a bony union with late repair of the nerve, because open operation removes the matrix for the callus and union may be lost. If the nerve is repaired, its functional convalescence is delayed by nonunion of the bone, but this is aided if union has occurred. Operations for nonunion of this region are fraught with the greatest problem to secure union. Every effort should be made to secure solid bony union by closed methods before resorting to open operation unless it is obvious that there is interposed tissue or a pseudoarthrosis present.

The traction spreaders should be arranged so that it is impossible for them to reach their pulley, thereby loosing traction for even a short period. The axis of the limb and the axis of the plaster case or supporting splint should coincide. The supporting hammock pieces should not be rough harsh canvas. This economy is destroyed by the poor convalescence and nursing demands. The greatest weights should be applied at the start when traction is efficient, not at the end. The three strip traction straps spiraling the forearm and arm (Fig. 7), reinforced with others, work better than the single wide strip. Where pressure exists cut away the adhesive and build up around it. Do not put cotton in to remove pressure. Remove adhesive with benzine and wash off with alcohol or witch hazel. The hair should be shaved, and where adhesive will not stick use Ambroid canoe glue. Do not depend upon spring traction unless you can arrange for a very long spring.

The time any fixation is required is as follows:

First period, until all tendency to displacement and over-riding is past. This varies with the type of fracture, its degree of reduction, whether compound or simple, and the strains it may be subjected to.

Second period, until all tendency to angulation is passed. Coaptation splints or a lessened degree of traction will do in this period.

Third period, when movement of the joints of the part is permitted within such extremes as will cause no pain.

Test the union by clinical examination and *x*-ray for callus formation. A union which from clinical examination may appear solid should not be subjected to too great a strain until the *x*-ray shows callus strength.

Remember that voluntary activation of the muscles of a limb in traction or in an immobilizing plaster which does not necessarily produce a movement of the joint will prevent atrophy of disuse, improve circulation, and promote callus formation. Where distraction has occurred, these movements with diminution of the traction weight are the only method to correct it.

Do not be afraid to afford a five weeks plus period for union in a humeral shaft. The more fragmentation, the better will be the union. The transverse or short oblique are the ones in which union is frequently delayed.

Where shaft and shoulder fractures have been treated correctly in the above periods, one can look for a return of function commensurate with the bone and soft part damage, and no one can accomplish more than that. It may take longer, but the patient will not trouble the surgeon later.

The dressings which are removable, such as the sling, axillary pad, and swathe, elephant head, etc., should be removed every few days according to the weather. The skin is washed with soap and water followed by alcohol and talcum powder. The dressings are then reapplied. This affords comfort to the patient, and permits such observation and changes of adjustment as are absolutely necessary.

The care of these lesions after removal of the retention dressings is all important to restore function. The problem is a healed fracture with an excess of callus which only time and circulation will remove, together with an atrophy of disuse and contracture of the muscles and all the soft parts. There is only one method to overcome atrophy, and that is by voluntary active movement done without the slightest pain.

Though a long article could be written on the treatment at this period, the following *law* will be sufficient if carefully studied and applied to each stage of progress in the convalescent care following gradual removal from retention dressings.

In the treatment of the contracture of any group of muscles of any joint without bone changes in which there is some movement, resisted movements in the direction of the plane in which movement has been lost will tend to restore function by developing the muscle or muscles which produce it by contraction, and at the same time will, by coordinated synergistic action, tend to relax the antagonists.[4] With patients in bed with other injuries this can be carried out by supporting the limb in a sling suspended from a height by a long cord. The sling allows movements otherwise not permitted by the atrophied muscles. Any passive movement which causes pain is usually doing more damage than good. My exception[2] to this is a method of stretching contracted shoulder muscles, which should not be used except where union is solid, late in convalescence. This causes pain, but should be used as I have described it and only when followed by marked relief of pain.

To restore shoulder function due to a fracture of the shaft or upper end when the patient can get out of bed or is ambulatory, proceed as follows:

Have the patient bend forward with the injured arm hanging vertically to a point easily tolerated by the shoulder. Then with the muscles relaxed move the *body* so that the arm is set swinging as a pendulum, forward, backward, sideways, then in a circle with the clock and against the clock. This stretches the muscles. This is followed by making the same movements actively, slower than the pendulum time with the body at rest, which makes the shoulder muscles do work, i.e., resisted motion in a position where gravity is overcome and

which aids coordination. Later graduated weights can be held in the hand while doing these exercises. As function increases the body is bent forward until the shoulder is performing at a point of marked upward extension of the arm. Be sure that the movement takes place in the scapulohumeral joint and not in the scapulothoracic joint. The first has a protective reflex mechanism which splints against any pain by spasm. The latter has not this mechanism and most of the movement of an injured shoulder is scapular, until the surgeon and time corrects this.

Where pain persists in the shoulder, hot stupes daily will give relief. For the loss of elbow function in shaft fractures, the above exercises are needed, to which is added resisted flexion, extension, pronation, and supination of the forearm. "Climbing the wall" will be most commonly done with a fixed shoulder by means of scapular action which should not be done. It is only good to measure return of the shoulder function. With a high pulley through which a rope is passed with handles attached to the ends, the well hand can pull up the injured one for stretching the abductors, but do not have the injured one pull the good one up. The adductor muscles are already strong enough, contracted, and need stretching.

As function is developed and strength is gained, a weighted or elastic wall exerciser can be used to resist every normal movement of the upper limb by simply changing the position of the patient's body to the device.

Swelling of the hand must be guarded against by elevation of the limb and hand above the heart, with active movements of the fingers. A good shoulder with a bad hand is the penalty for not doing this.

A patient in bed with too much elevation of the fracture site above the heart after the acute swelling has subsided, may develop a postural ischemia of the callus with delayed union. In the absence of swelling, short periods of dependency will help to vascularize the callus.

Physical therapy should be the simplest and only applied by one with experience and skill. Radiant heat with the gentlest massage to improve circulation are all I usually require. I have too frequently seen much pain and injury produced in fracture cases by misguided physical therapy endeavoring to speed Nature's processes.

X-rays should always be taken in two planes, especially in this region. Films should be used to record position instead of fluoroscopic reports.

Each detail of treatment should be carried out by the doctor responsible for the case, and not left to inexperienced ones to do it for him.

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FRACTURES IN THE FOREARM—EXCEPT COLLES'

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MANY factors play a part in the relatively high frequency of forearm fractures. The bones are light, they are subjected to the primary stress in falls on the outstretched hand, they receive the vulnerating force in warding off blows, and their excursion is restricted at the elbow by a hinge joint.

Fractures of one or both bones of the forearm comprise about one-fifth of the fractures in the entire body. The radius is involved approximately twice as often as the ulna. Excluding fractures of the lower extremities of the bones, the ratio drops to 1.4:1.

GENERAL CONSIDERATIONS

There are certain cardinal principles to be observed in the treatment of all fractures. These cannot be overstressed and will be stated here even at the expense of repetition.

1. Promptness. Emergency treatment, both first-aid and early reduction.
2. Thoroughness of reduction.
3. Gentleness of manipulation.
4. Individualization.

Promptness: This means protection against further injury to the part by the best fixation available that will permit transportation. At the first possible moment any necessary care of shock should be instituted, and the patient examined for any complicating injuries to viscera, vessels, nerves, etc. Shock is the most frequent condition in the patient that justifies postponement of the fracture treatment. Swelling indicates action rather than delay, and is best reduced by early reposition of fragments. Exudation beneath the deep fascia and muscles causes distention and a bulging of the tissues resulting in shortening. Coagulation, fibrin formation and cellular exudate follow delay and produce loss of tissue "workability" made even worse as soon as the clotted blood partakes of a gum-like consistency.

Adequate assistants, the use of the fluorscope, satisfactory anesthesia, local or ether, are desirable. In acute fracture (hours) local anesthesia by injection of procaine hydrochloride solution at the fracture site is most satisfactory in preventing pain and producing relaxation. The conscious patient can very often give most helpful co-operation. Early reduction means easier and better reposition of parts with diminution in the necessary number of such attempts that might otherwise be needed.

Gentleness of manipulation: This means a respect for tissues and applies just as aptly to the closed as to the open methods of treatment. True, considerable force is often necessary to secure a proper reduction. Relaxation is obtained by use of anesthesia and position of muscle equilibrium, due consideration is given to the proximity of vital structures, and then, with conditions favorable, just that amount of force and manipulation necessary to obtain and maintain reduction is applied. Eliciting crepitus is not necessary for diagnosis. It may be harmful. All movements affecting the fracture site should be undertaken slowly and gently with gradually increasing traction in the direction of muscle equilibrium or balance. Rough

movements defeat the purpose by causing spasm of muscles affecting the fragments. Roughness may result in damage to vessels, nerves, muscles, skin, or even in further damage to the bony structure itself. There will be instances in which ill-advised, repeated, rough manipulation in attempts to obtain a difficult reduction will result in far more tissue damage than would attend an early open reduction.

Thoroughness: If success is to be our reward, thoroughness is essential and yet it must not be overemphasized. A cabinet maker's or perfect reduction does not insure perfect function, nor does the absence of perfect reduction necessarily indicate diminished function. It is here that individuality and judgment play an important role. In the past there were only two parties concerned in a fracture result; the patient and the surgeon. A fair anatomic result with fair or good function satisfied both. When the Roentgen ray entered the field, there was born at once the desire to obtain a so-called Roentgen or cabinet maker's reduction. This resulted in an associated increase in the number of open reductions in the attempt to accomplish this. Next, a third party entered the field—namely, the insurance companies—and our results are now scrutinized by this third party with an impartial eye.

In some respects this has been advantageous to the patients, but in other respects it has led to a desire to obtain the so-called perfect roentgen or cabinet maker's reduction. Why? It is due to the fact that a jury is more than likely to judge the result by the roentgenographic evidence and not by the degree of function obtained. Hence, we find that more open reductions are resorted to in an endeavor to meet this demand. Then, too, if the patient or his family view the film, which should always be insisted upon, they ask for the open reduction, desiring a perfect result.

Open reduction may be fraught with great danger of loss of function, limb or even life. To teach the promiscuous employment of this method will bring sorrow to many in its application. This refinement should be resorted to only after much deliberation. If experience has shown that the type of fracture under consideration will heal with good function despite its displacement, let sleeping dogs lie and treat the fracture by the closed method.

Factors determining the individuality of treatment: (a) *Age and occupation:* Take as an illustration a fracture of both bones of the forearm. In a young child, Nature (in the guise of Wolff's law) and other growth factors, may bring about excellent function in a year or two, in spite of more or less poor alignment. Imagine a second type of patient, a violin player 35 years of age, with the same fracture. This man will more than likely need a cabinet maker's reduction, possibly necessitating open treatment to accomplish it, whereas a third patient, an elderly man—a night watchman or a retired banker—would be willing to accept loss of rotation or some angulation and shortening, especially if he were in poor physical condition. Judgment tells us that only one of the three requires an operation. It is, of course, understood that interposition of soft parts demands correction in all three instances.

(b) *Constitutional disease* may be serious enough to justify being satisfied with some deformity and loss of some function.

Consider, for example, a man of 60 years, who sustained a fracture of mid-shaft of radius and ulna. His general condition was poor with acute diffuse bronchitis, hypertension and obesity. Under local anesthesia the fragments could be reduced but their position could not be maintained. After several trials under the fluorscope it seemed best to accept defeat and prognosticate dysfunction but with the ability to carry on administrative work with left handed disability. The result was excellent for this situation, although there was shortening and about 60 per cent loss of rotation. The patient was most pleased.

(c) *Injury to blood supply:* This may be so extensive and serious that any manipula-

tion may result disastrously. Weight traction may be the best method to employ.

(d) *Type of fracture:* Comminuted shaft fractures give the best results when treated by traction. Alignment and length are easily obtained. Merely because of irregularity of fragment arrangement it would be foolhardy and as a rule disasterous to attempt open reduction. Multiplicity of fractures with accompanying visceral complications frequently forces the acceptance of bone deformity with possible dysfunction.

(e) *Site of fracture:* The nearer a joint, the more accurate should be the reduction in order to obtain the best function, and yet there are individual factors that make exceptions. A fracture near or into a joint in a younger man requires a more radical attempt to free the joint or to obtain more nearly perfect reduction.

(f) *Growth factor:* Epiphyseal separations are almost a law unto themselves, in that remarkable results are obtained in spite of poor reduction and much early deformity. The growing bone will perform wonders with its ability to readjust its anatomy to approximate the normal. In a series of 110 cases published by Eliason and Ferguson, the following conclusions were drawn:

1. Perfect reposition of the displaced epiphysis does not necessarily insure subsequent normal growth.

2. Perfect function often follows despite considerable displacement.

3. The incidence of growth interference is a low one and is no respector of good or bad reposition of parts. Premature ossification occurred in three cases, all of which had perfect reduction.

4. Results would seem to indicate that a fair degree of deformity and good function can go hand in hand.

TECHNIQUE OF EXAMINATION

Examination of the injured forearm must be thorough, atraumatic, and as nearly painless as possible. The ambulatory patient is seated on a chair with both forearms resting on a small table, and the examiner seats himself on the opposite side. Visible deformity makes the diagnosis obvious, but does not dispense with the need for a complete examination. Swelling, ecchymosis, and bleb formation are noted. By careful palpation and comparison of the bony landmarks and contours, slight degrees of bony deformity, such as thickening, angulation or irregularity of a shaft, may be found. The possibility of multiple fractures of any bone must be kept in mind. Even in the absence of any deformity, sharply localized, wincing tenderness at some point in a bone usually means fracture. Crepitus and preternatural mobility should be sought very cautiously, if at all.

Finally, the color and temperature of the hand, the character of the radial pulse and the presence of sensory or motor impairments must be recorded.

RULES FOR SPLINTING FOREARM FRACTURES

Fix the joints above and below the fracture.

Wooden splints should be padded to fit the contour of the part and should be wider than the diameter of the forearm. (Fig. 1, A and B.)

Plaster splints should be molded and their edges should not overlap.

The upper end of the right angled splint should be a finger's breadth from the axillary fold.

Avoid pressure points, particularly over the head of the radius, the internal epicondyle, and the styloid of the ulna.

Splints should not be so tight that they will not spring on pressure between the thumb and forefinger of the surgeon's hand.

Do not bind tightly at the elbow.

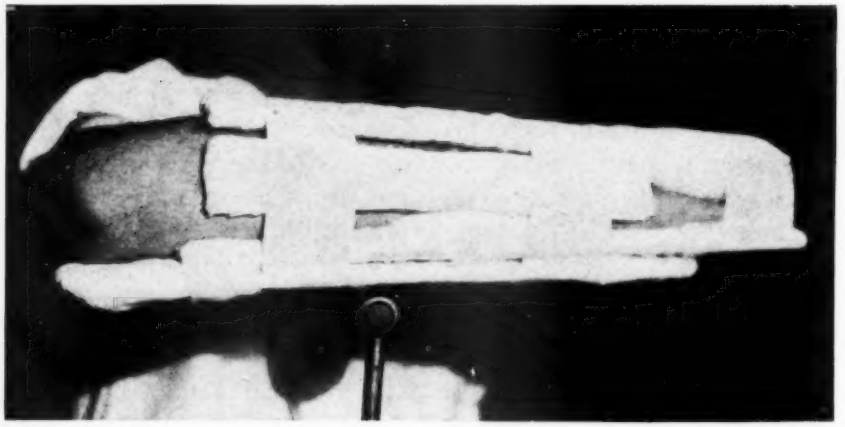
Maintain elbow fixation to the full time limit in children (joint function is easily and rapidly restored).

The surgeon should see the patient within six hours after reduction in order to ascertain the amount of pain the patient is having and to observe the appearance of the hand. After proper reduction and a

proper dressing the patient should experience increasing comfort rather than pain or discomfort.

THE USE OF UNPADDED CASTS

Recently the use of unpadded casts for immobilization of forearm fractures has become more frequent. Properly applied, such a cast has distinct advantages. Maximum immobilization of the fracture site can be obtained. If the cast is applied after swelling subsides, the need for further changes of dressings and splints is practically eliminated. Children and obstreperous adults cannot loosen or pre-



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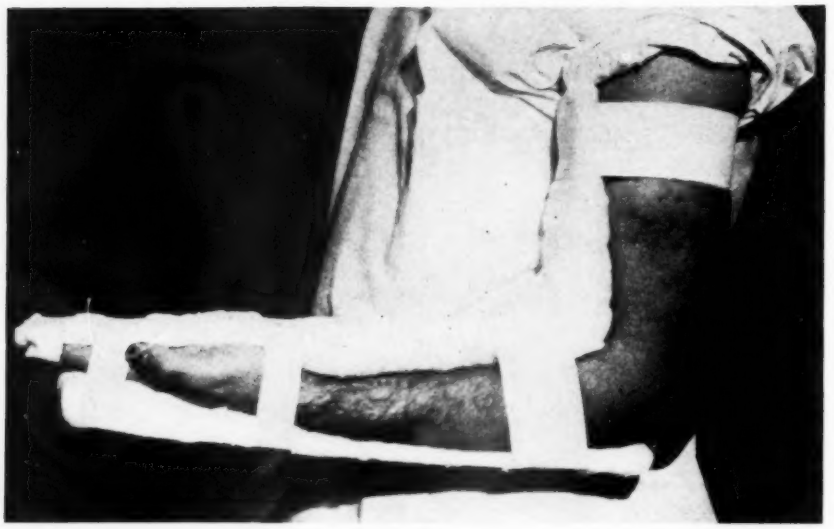

B

FIG. 1. Dressings for fractures of the shafts of the radius and ulna. A, the anterior or palmar splint padded for contour, fixes the fingers for the first ten days. The internal right-angled splint fixes the elbow joint. Note the gravity or ulnar splint to prevent sagging of this bone. The dorsal splint reaches to finger tips for the first ten days. A bandage encompasses all splints. B, (See text for indications.) The anterior right angled splint, padded for contour, should extend from finger tips (for first ten days) to anterior axillary fold. The dorsal forearm splint may stop at metacarpal ends. A bandage covers all splints. This makes a very irksome dressing at times.

At least one splint should fix the fingers for ten days in cases where the type of fracture makes the maintenance of reposition uncertain.

The sling should be a broad triangle and not simply a wrist band.

Unpadded casts when used are applied only after subsidence of swelling.

maturely remove the cast. Most important, the cast permits active use of the extremity, which may be started in many cases as soon as the plaster is dry. Such active use appears to be superior to any formal physical therapy in preventing stiffness, muscle atrophy and joint changes.

In selected cases in which fractures are incomplete or in good position with a negligible likelihood of displacement, the patient may be urged to return to work immediately after application of the cast. A number have been able to resume their occupations (as pharmacist, locksmith, machinist) with but a few days' loss of time.

Danger attends the use of a snug and rigid cast immediately after injury and reduction. Also, application of the cast while the forearm is swollen results in a loose cast when the swelling subsides.

TECHNIQUE OF APPLICATION OF UNPADDED CASTS

The elbow is held at a right angle with the wrist midway between palmar and dorsal flexion. The hand is held in mid-pronation unless the type of fracture makes mid-position or supination especially desirable. Depending on the size of the arm, plaster bandage four or six inches wide is used. The standard length is five yards. Slow setting plaster is preferable.

With an assistant holding the upper arm and another making gentle traction on the hand, the surgeon measures, with a strip of bandage, the length from the posterior axillary fold down the back of the arm over the point of the elbow and the extensor surface of the forearm to the knuckles. On the flexor surface the length from the distal palmar crease to the elbow is measured.

A plaster bandage is dipped until dripping wet, then without wringing is rolled out to the first of the measured lengths, and reduplicated to make a slab. This is applied from the posterior axillary fold over the point of the elbow to the knuckles, and is slit at both sides of the elbow and folded over. A second bandage is dipped, rolled out to the second measured length and reduplicated, but only one half or two thirds of the bandage is used. This slab is applied to the flexor surface of the forearm from the distal palmar crease to the elbow. Plaster bandage is then wrapped, without any tension, around and up the arm from the distal ends of the plaster slabs to the proximal. Depending on the size of the arm, three or four bandages usually suffice for the whole dressing.

Fig. 2. Unpadded cast for forearm fractures. Not quite close enough to the axillary fold for the average case. A sketch of the fracture and the dates of fracture, of casting and of removal are faintly visible.

While the plaster is setting, the surgeon makes pressure over the interosseous space to maintain its width, when necessary. An assistant meanwhile molds the plaster firmly about the bony contours of the hand, wrist and elbow. The plaster is trimmed in the palm to allow full flexion of the fingers and thumb. At the axillary end the edges are turned down and rubbed until smooth and rounded. The date of fracture, the date of application of the cast and the date set for removal of the cast, as well as a sketch of the fracture, should be inscribed on the cast. (Fig. 2.)

APPLIED ANATOMY

Restoration of function is the ultimate goal of fracture treatment. In many cases the degree of anatomical restoration is but a secondary consideration. This does not mean, however, that one is qualified to treat fractures without a detailed knowledge of the anatomy involved—quite the contrary. Only through familiarity with the basic anatomical principles is the surgeon occasionally able to accept slight deformity of a part with a reasonable expectation of functional restoration.

In other instances anatomy and function go hand in hand, and a poor anatomical result presages corresponding functional impairment. This is especially true in fractures of the forearm, the rotary movements of which are so necessary to the proper function of the hand.

The forearm is largest in its upper portion where the muscles are thickest. The bones are most easily palpated from the postero-lateral aspect, which is the elective operative approach. The ulna is subcutaneous throughout its entire length and is decidedly posterior to the radius in its upper half. The ulna is the chief forearm bone concerned in the maintenance of fixed stability of the elbow; the radius is the only one to articulate directly with the carpus. Rotation in the forearm occurs around the ulna as an axis, by reason of the action of the radius, which rotates about an axis coninciding with the line passing through its neck and extending through the head of the ulna. The amount of rotation possible is about 160° (Piersol) but is often less in normal individuals.

When in mid-position between pronation and supination the bones are more nearly parallel than in any other position and the interosseous space is the widest. The direction of the fibers in this interosseous membrane is from above on the radius obliquely downward to the ulna.

The ulna is longer than the radius and articulates with it at both extremities. The supinator brevis and the pronator quadratus are the two forearm muscles intimately related to the radius and ulna. Other muscles attached to both bones are not primarily concerned with forearm motion. The long flexor and extensor muscles of the fingers take their origin in the forearm, being attached to the two bones and the interosseous membrane.

Further anatomical points will be considered with each individual type of fracture.

OLECRANON

Anatomy: The ulna articulates with the humerus through the olecranon and with the head of the radius through the lesser sigmoid cavity. The olecranon is a cubical hooked process with the greater sigmoid cavity as its articular surface. It is notched at the base of the coronoid process, a point of weakness. The point or break is not subcutaneous. The posterior surface or "point" of the olecranon is triangular, subcutaneous, and has the triceps muscle attached to it. The subcutaneous portion is covered by a bursa. The olecranon before the fourteenth year, prior to full development, is on a plane anterior to the plane of the humerus with the elbow in right angled flexion, hence the stated infrequency of olecranon fractures in youth as compared to adults. In our own group this did not hold. The incidence in the first two decades equalled that of later ten year age periods.

The epiphyseal line is small, above the junction of the coronoid and olecranon, and is oblique from above, downward and backward. A divided epiphysis is of relatively frequent occurrence and should not be confused with fracture. Separation of this epiphysis is very rare.

Etiology: Fractures here are due to direct violence, muscular action, or both working together. Cases have been reported where the beak has been broken by hyperextension. The fracture line is usually transverse or oblique. Direct violence often produces comminution. The degree of separation de-

pends upon the pull of the triceps superimposed on a tear in the periosteum and capsular ligaments.

Diagnosis: If a simple chipping of the point of the olecranon has occurred, the symptoms are merely localized pain and tenderness, some swelling, possibly a palpable fragment of bone, and slight voluntary limitation of extension. If the fracture line enters the joint, as all complete ones must, there is added joint swelling, instability of the joint and marked diminution of the power of extension. Crepitus may be elicited if the fragments are not too widely separated. The defect between the fragments may be easily palpable.

Often the olecranon is pulled above its normal relation to the condyles. In many instances *x*-ray confirmation of this fracture is necessary, especially to differentiate it from a chronic bursitis. The fracture may be associated with anterior dislocation of both bones at the elbow. Fractures of the head and the neck of the radius, the coronoid, or of the lower end of the humerus (especially the condyles) are also reported in this connection.

Treatment and prognosis: Classified on the basis of treatment our series of olecranon fractures may be divided into four groups:

1. Those with no separation of fragments. These are dressed on an internal right angled splint with a forearm sling.

2. Those with slight displacement which can be satisfactorily reduced. In this group the arm is best dressed in extension with an anterior molded plaster splint. (Fig. 3.) An adhesive loop over the upper fragment may help to maintain it in position.

3. Those with marked separation, comminution or compounding. Open operation is usually necessary. The fragments may be fixed in approximation with catgut fascia lata or wire. We no longer use kangaroo tendon.

4. Those in which the olecranon fracture is only part of the picture of "smashed elbow." Individualize. Every one of these cases with different combinations of fractures extending into the elbow joint from all three bones is a law in itself.

The after care in the uncomplicated fractures is essentially the same for all. Start slight flexion after two weeks and gradually increase motion up to four or five weeks when the splints are removed. Magnuson, after wiring his cases, does not splint them and starts active motion within a week. Flexion is more important than extension in the final result, if limitation must exist. Hence when such is expected the elbow should be dressed in the right angled position.

Fig. 3. Anterior molded plaster splint used for olecranon fractures. The hand is almost free.

End-results have been evaluated after both open and closed methods of treatment by Hawley, Jones, and Daland. They are not in agreement. In our own group we do not believe they are comparable since the indications were different. Good func-

tion may be expected in either case. The type of union, bony or fibrous, is not the important consideration in prognosis but

Fig. 4. Horse-collar dressing in the Jones position, used for injuries about the elbow when there is no danger of rotation deformity.

rather the stability of the joint and the amount of intra-articular callus.

CORONOID PROCESS

Anatomy: This process arises from the anterior surface of the shaft of the ulna. Its upper face articulates with the trochlea. Its anterior surface arises to a point nearer its outer side. The joint capsule attaches just below its articular edge. The brachialis anticus muscle inserts in the tuberosity near its base.

Etiology: This fracture, which is rare, is usually associated with posterior dislocation at the elbow. Indirect violence transmitted through the forearm is the common cause. Muscle action has been reported as an etiological factor, but certainly cannot be a frequent one, since the fracture line is usually above the attachment of the brachialis anticus. Incidentally, direct crushing violence to the elbow may break the coronoid.

Diagnosis: Swelling and tenderness in the antecubital fossa to the inner side of the biceps tendon may be the only signs. Forced flexion may be painful. Occasionally in a very thin subject the loose fragment may be felt or crepitus elicited. Tendency for a posterior dislocation of both bones at the elbow to recur easily may lead to suspicion of this fracture. The *x*-ray affords the only means of positive diagnosis in the majority of cases. Wide displacement is rare because the fragments are usually held in apposition by periosteum, capsular ligament, and the expansion of the brachialis anticus attachment.

Treatment and prognosis: This fracture is best dressed in hyperflexion. The senior author's plaster hyperflexion dressing or the Jones position may be used. (Fig. 4.) Begin slight extension and massage in ten days. Increase motion gradually but not to the extent of causing pain. After three weeks (from the beginning in those with no displacement) an internal right angled splint may be applied or an unpadded cast. Splints are removed in five to six weeks and a sling is then used intermittently to prevent fatigue. The prognosis is good in youth but more guarded in older people, especially those with arthritic changes. In old cases in which the fragment interferes with the joint by mechanical pressure excision may be necessary (Speed).

SHAFT OF THE ULNA (ALONE)

Anatomy: The shaft of the ulna, which is somewhat triangular in shape, diminishes in size and strength from above downward. In the upper third, the bone curves backward and outward, then inward until at the lower third it again bends outward and forward. It has three borders. The outer, or interosseous border, is very sharp in the middle two fourths where it gives origin to the interosseous membrane. The nutrient artery running upward enters a little above the middle of the bone. The lower end of the shaft is comparatively slender and somewhat cylindrical in shape. The ulna

does not articulate with the carpus at its lower end.

Etiology: Fractures of the shaft of the ulna alone are usually the result of direct violence, commonly a blow on the forearm flexed and raised over the head to protect it from injury (parry fracture). Theoretically, immunity of the ulna to fracturing force transmitted through the hand would be expected, since this bone does not articulate at its lower end with the carpus. Practically this does not hold, and fall on the extended pronated hand has been encountered as a frequent etiological factor.

Diagnosis: The shaft of the ulna may be broken at any level. The fracture is frequently compound because the bone is subcutaneous throughout its length. The usual line of fracture is transverse or slightly oblique. It may be comminuted. The usual signs and symptoms of fracture are present. Often there is little interference with function. In fractures of the upper third, the upper fragment is often flexed and abducted. This fracture is very commonly associated with dislocation of the radial head. In fractures of the middle and lower third the pronator quadratus displaces the lower fragment towards the radius. Shortening in these fractures is absent if there is no associated fracture or dislocation of the radius. Radial nerve palsy may occur but is rarely of serious nature.

Treatment and prognosis: As a rule the fractures in this group do not show great displacement and often manipulation is not necessary. When reduction is indicated the method varies with the level of fracture. In the upper third, fracture of the ulna is often associated with dislocation of the radial head. The radius should be reduced first by applying traction and rotating and manipulating with pressure over the head. When this reduction has been obtained, flex the elbow and externally rotate the forearm. Then, using the radius as a lever against the lower humerus and making traction, reduce the ulna. If, when dislocation of the radius is associated, reduction of both cannot be obtained or maintained, the patient may be given a trial on continuous traction before resorting to open reduction. In the middle third there is no routine procedure for reduction. Manipulate under fluoroscopic guidance and dress in the position in which reduction is best maintained. Fractures in the lower third are difficult to reduce and maintain. Flex the elbow, grasp the forearm above and the hand or wrist below the fracture, produce strong pronation and make traction on the internal lateral ligament of the wrist by abducting the hand to the radial side. These fractures are dressed on molded plaster forearm splints with an internal right angle splint to fix the elbow. An unpadded cast may be applied when the swelling subsides. Splinting is continued for a period of four to five weeks. Open reduction is seldom necessary but should be resorted to if a satisfactory closed one cannot be obtained, particularly in respect to maintenance of the interosseous space. Roger Anderson uses a towel clip to grasp the lower ulnar fragment and pull it away from the radius in fractures of the lower third. He then incorporates the clip in a plaster dressing to maintain the position. Prognosis is good except for those fractures of the upper third complicated by dislocation of the radial head. Here prognosis is more guarded, as it is very difficult to keep both the dislocation and the fracture reduced. These cases may have to be opened to reconstruct the orbicular ligament (Spiers).

HEAD AND NECK OF THE RADIUS

Anatomy: The head is an imperfect circular enlargement with a shallow cuplike depression on top which articulates with the capitellum. Its margin is smooth and articulates with the ulna at the lesser sigmoid cavity. Neither the head nor the rim is symmetrical. The anteroposterior diameter of the head is the greater, the anterior rim of the cup is the thicker. The plane of the head usually looks forward. The neck is constricted and is about one

inch long. The epiphysis forms but a portion of the head. The head and the upper part of the neck are intra articular, made so by the orbicular ligament.

Etiology: Indirect violence transmitted through a fall on the pronated hand has been accepted by the majority as the commonest cause of this fracture. However, in a recent small series reviewed by us, fall on the elbow was encountered more frequently as the causal factor. Cutler and Speed both found direct violence the usual cause. Many writers mention a torsion or twisting as possibly causing this fracture, but this mechanism in such cases is difficult to appreciate since no muscles, ligaments, or tendons are intimately attached to either the head or neck. Fracture of the head is approximately four times as frequent as fracture of the neck. Epiphyseal separation is rare. Fracture of the head occurs most frequently in adults; that of the neck is not uncommon in children.

Diagnosis: A. *Head:* All types of fracture occur here. Symptoms vary somewhat according to the type. Since the fractures are intracapsular the displacement is usually not great. There is localized pain and tenderness over the head of the radius. Crepitus is rarely encountered in this condition. There is more or less disability at the elbow joint. Supination is the motion chiefly limited, although displacement of a fragment inward may completely limit flexion. If a fragment is displaced outward over the external condyle it may be easily palpated. Downward displacement means that the orbicular ligament has been torn. Pain may be referred to the radial side of the wrist from pressure on the radial nerve (Speed). This fracture is commonly associated with fracture of the external condyle of the humerus, dislocation of the radius, posterior dislocation of both bones at the elbow, fracture of the coronoid, fracture of the olecranon, or with fracture of the shaft of the ulna. In patients between the ages of 5 and 7 there is a possibility of an epiphyseal separation. Except for the muffled or soft crepitus and the age of the patient, this differs in no respect from fracture.

B. *Neck:* In uncomplicated cases the deformity is rather uniform in complete fractures. The upper fragment is bowed outward and flexed. This deformity is probably accounted for by the fact that the tissues are on stretch from the pull of the supinator brevis muscle, which does not attach to the fragment but simply acts on the neighboring structures. Localized pain, tenderness, and swelling are the common findings. Deformity and crepitus may be demonstrable. Unless the fracture is incomplete or impacted the head does not rotate with the shaft. There is limitation of rotation, especially supination, but flexion and extension are less painful than in fractures of the head. A sudden jar on the fist with the wrist rigid gives pain at the fracture site.

If the fracture of the head is in good position (fissured, longitudinal or impacted) the elbow may be fixed on an internal right angled splint, or in the Jones position by a "horse collar" dressing. (Fig. 4.) Gentle motion and massage are started after ten days. An unpadded cast (Fig. 2) may be applied at the outset instead of the splint or horse collar dressing. If it is used, active exercise of the arm may be started immediately. The total period of fixation is from three to six weeks. With wide separation of a fragment downward or outward, the same treatment may be used.

If the fragment is displaced into the joint it must be excised. In fractures of the neck reduce by closed method if possible and dress as above. If this cannot be done open operation is indicated. Do not excise the head of the radius in growing individuals if this can be avoided. Good functional results are obtained after both types of treatment. There may be some limitation of motion in older people, especially supination. Magnuson starts active motion within twenty-four hours after excision of the head and reports perfect results as to function and strength.

THE SHAFT OF THE RADIUS (ALONE)

Anatomy: Immediately below the neck, the shaft bends outward and curves slightly forward at the lower end. The bicipital tuberosity is just below the neck on the inner aspect of the front of the shaft. The bone has only one really distinct border, that for attachment of the interosseous membrane. The upper portion of the shaft is cylindrical, changing at the junction of the upper and middle thirds to a triangular shape, this latter becoming more rounded near the lower end, finally to become flattened out. With the hand in the thumb-up position, the upper two thirds of the radius take a position external to the ulna, a point to be borne in mind when splinting in order that the broken ends will not be bowed over the ulna with a resultant poor function. The anterior surface low down is slightly concave. The nutrient artery enters the inner aspect of the bone just above the middle and runs in an upward direction. The upper portion of the shaft is rarely broken because of its protected position and because the weakest part is not in this region. Below this the union of the secondary and primary curves, changes in shape of the bone, and the transition of muscles to tendons all combine as causes of vulnerability. Muscular action must be considered in fractures of the radial shaft. The biceps muscle attaches to the bicipital tuberosity and the supinator brevis muscle just below. The pronator radii teres muscle attaches at about the middle of the shaft and the pronator quadratus muscle at the lower extremity. These are the muscles chiefly involved.

Etiology: Either indirect or direct violence may fracture the shaft of the radius. Fracture of the lower third due to a fall on the hand is especially common in children. A twisting force or muscular action may cause this type of fracture. Fractures are much less frequent above the insertion of the pronator radii teres than below.

Diagnosis: The fracture varies in type. The classical symptoms are usually present. Shortening is not pronounced because of the splinting action of the ulna. If the fracture is complete the head of the radius fails to rotate with the hand. Deformity varies with the level of the fracture. Above the pronator radii teres muscle the upper fragment is flexed and supinated by the biceps and supinator brevis muscles. The lower fragment is adducted and pronated by the two pronator muscles. When the fracture line is below the insertion of the pronator radii teres muscle the upper fragment is flexed, adducted, and in mid-position between pronation and supination. When the radius alone is broken in the lower shaft one and a half to two inches above the wrist the lower fragment is usually displaced anteriorly. Variations from the typical deformities are encountered.

Treatment and prognosis: Particularly in this group of fractures must the patient be under anesthesia with the elbow flexed to obtain muscle relaxation. Counter traction is made above the elbow by an assistant. The operator, standing at patient's head, grasps the patient's hand (often a hand-shake grasp) and uses the other hand to manipulate. (Fig. 5.) The ulna is used as a fulcrum. Because of the muscle actions considered above, we would expect fractures above the pronator radii teres muscle to be best dressed in supination and those below in mid position. Practically this does not always hold and emphasizes the fact that the best rule is to dress the part in the position in which reduction is best maintained as tested under the fluoroscope. Here, as in fracture of the ulnar shaft alone, the displaced fragment must be replaced at least partially end to end to restore and maintain length, so important for rotation at the wrist. These fractures are well treated in unpadded plaster casts. Molded plaster splints may be used. Fixation is maintained for from three to six weeks. The elbow is fixed for the full duration in those fractures of the upper third but may be mobilized

earlier in those at the lower levels. Start guarded active motion at the elbow and wrist in ten days to two weeks. Open reduction is often necessary in these cases. The Lane plate has been found satisfactory for internal fixation when indicated. Prognosis is good. Occasionally non union occurs in the lower end, more often after an open operation. Magnuson stresses the importance of associated involvement of the distal radio-ulnar joint in displaced fractures of the radius alone. The point of the radius will not fit the ulnar notch in complete supination, if there is radial shortening. He recommends placing felt pads over the lower end of the bones and binding with circular adhesive to maintain the close and proper relation of the lower ends of the two bones.

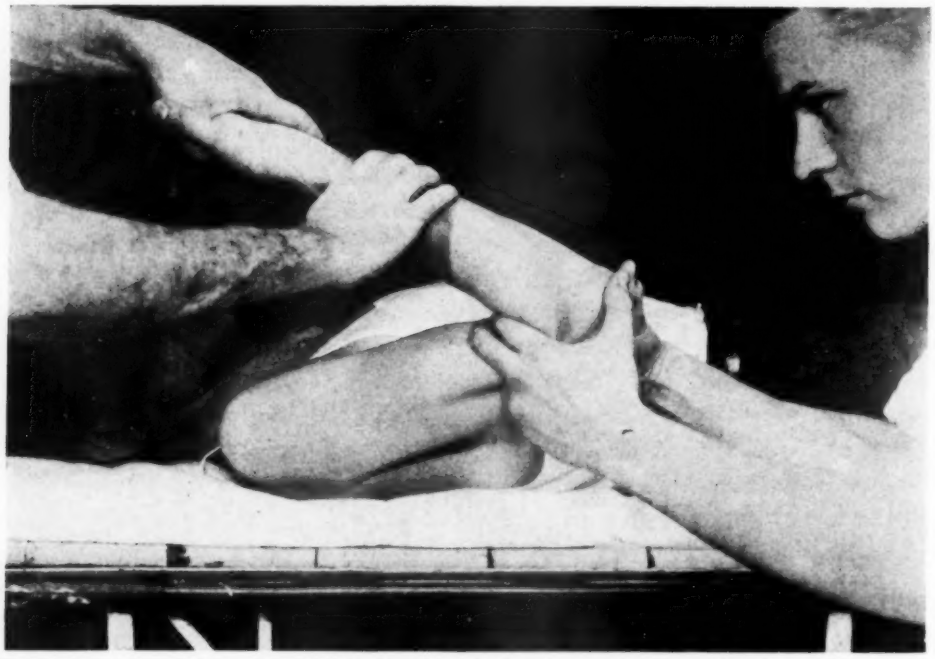

Fig. 5. Positions of surgeon (at the head) and of assistant for the reduction of fractures of the shafts of the forearm bones.

SHAFTS OF BOTH BONES

Anatomy: This has been covered in preceding sections.

Etiology: Either direct or indirect violence may fracture both bones of the forearm. Direct violence usually breaks both bones at the same level. Indirect violence from a fall on the hand usually breaks the radius at a higher level than the ulna. This is due to the fact that the radius first breaks because the force is transmitted to it alone through the wrist. The force continues and is transmitted to the ulna which is pulled upon by the driven radius through the interosseous membrane, the fibres of which are attached at a lower level on the ulna; hence the lower cross strain and the consequent lower fracture. As in fractures of the radius alone, the frequency of breaks at various levels increases from above downward.

Diagnosis: Symptoms depend on the type, which is varied, the force, and the level of fracture. Pain, tenderness, swelling and varying degrees of disability are present. Abnormal mobility is easily elicited in most cases. Shortening is often not very pronounced because of the restraining influences of the interosseous membrane. Angulation is the usual deformity: rotation of one or more fragments may occur. In all combined fractures of the forearm bones the interosseous space is narrowed. In fractures above the pronator radii teres muscle the supinators act on the radius as in fractures of this bone alone. Fractures

about the middle usually show the two upper fragments flexed and drawn together by the pronator radii teres muscle.

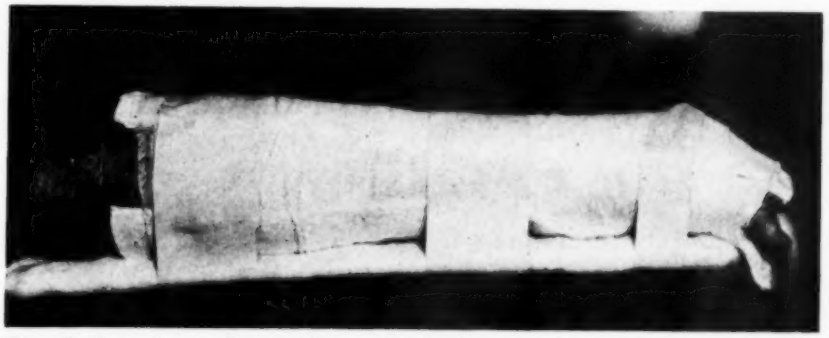

Fig. 6. Anterior and posterior molded plaster splints, and internal right-angled wooden splint, applied immediately after reduction of the fracture. The forearm plaster splints may be replaced by a "sugar tong" type. This dressing is applicable for the majority of fractures in the forearm here under discussion.

The two lower fragments are drawn together and rotated by the pronator quadratus muscle. The lower fragments usually lie posteriorly. The lower end of the upper radial fragment is frequently adducted and lies between the lower fragments. In addition there is usually an inward and backward bowing. The line of fracture is usually transverse oft times with a small triangular comminution in one or both bones or it may be of the "step" type. When a child falls on the palm and sustains a fracture, usually both bones break, and frequently in the lower portion about one to one and a half inches above the epiphyseal line (adolescent level). The fracture of the radius is more often complete than that of the ulna. The upper ends of the lower fragments are apposed by the pronator quadratus muscle. Overlapping with shortening is more pronounced here than in any other part of the shaft, probably because of the loss of interosseous membrane restraint and the absence of muscle attachments. These are the usual deformities explainable by muscle action, but other factors operate to vary them: direction and type of fracture line, direct force, etc.

Treatment and prognosis: As in fractures of the shaft of either bone alone, the method of reduction varies with the level. General anesthesia is usually required. The elbow is flexed and traction with countertraction established before any manipulation is started. When the fracture is in the upper third, it is usually best to reduce the ulna first since it is the larger bone at this level and provides a better fulcrum. Then one should pronate and increase flexion in attempting to reduce the radius. In the lower third reduce the radius first. Make traction and dorsal flexion; supinate and adduct toward the ulna to engage the radial fragments; then pronate to complete the reduction. If this is successful the radius can be used as a fulcrum to aid in reduction of the ulna. If the above outlined manipulations under fluoroscopic guidance fail to obtain a satisfactory reduction, skin or skeletal (Anderson or Bohler) traction may be applied. Occasion for such use has not confronted us as yet. In green stick fractures over correct the deformity or it will recur. This may necessitate completing the fracture.

Often fractures of both bones of the forearm require open reduction because of interposition of soft parts or failure to maintain a closed reduction which will preserve the interosseous space. The necessity for open reduction is particularly great in fractures of the upper third of the bones. Often internal fixation is not necessary. Sutures, intramedullary bone pegs, or plates may be used. Bisgard uses pins to fix the fragments and passes the ends of

the pins on through against the other bone to maintain the interosseous space.

After either closed or open reduction the arm may be dressed in mid-position on anterior and posterior molded plaster splints with an internal right angled splint to fix the elbow. (Fig. 6.) The "sugar tong" plaster splint may be used in place of the two separate forearm splints. Here it is important to remember the normal lateral position of the radial shaft in relation to the ulna. The Bolles splint cares for this admirably and accomplishes that all important preservation of the interosseous space. In most cases it is wise to fix the fingers for at least ten days to prevent displacement of fragments by action of the long flexor and extensor muscles attaching to the forearm bones. Theoretically fractures above the pronator radii teres should be dressed in full supination. We have not often found this advisable or necessary although some authors dress a majority of this group of fractures in supination (Speed, Hitzrot). Unpadded plaster casts may be applied when the arm is first redressed. The prognosis is guardedly good. Occasional non-union is encountered, especially in the lower third. When limitation of motion occurs it results in comparative loss of supination.

Open reduction: There are three indications for open reduction in an acute fracture: namely, failure to obtain a satisfactory reduction by the closed method; failure to maintain a satisfactory reduction that lasts; and, probably the most important, the surgeon's ability to obtain a satisfactory result if he resorts to an open reduction. In order to have a clear understanding we must explain what "satisfactory" should mean in each of the three instances. Here, again, individuality enters the field. As stated above, the prime aim in all fracture treatment is restoration of function, especially that necessary for the patient's livelihood. At once we are faced with the disturbing factors of age and disease, the degree of local injury to blood supply, the type of fracture, etc.

Do not be in too great a hurry to advocate operative treatment for non-union in these bones. Rather apply a leather, celluloid or mache cuff and put the part at work. We have seen such treatment result in union after eighteen months of imperfect or non-union.

Vicious union: Such union does not of itself mean serious dysfunction; therefore, sane judgment for each individual case is essential. To attempt to correct a vicious position with shortening in a seven weeks old fracture may be justified in a youngster but not in a hemiplegic or a patient with Buerger's disease. Fit the treatment to the patient and not the patient to the treatment.

Compound fractures: These fractures require immediate operation, débridement and internal fixation if necessary. If the wound is infected it is best not to close it.

Complications: The above forearm fractures are not infrequently complicated, with resultant loss of function. In 207 cases reviewed, the following were noted:

Infection and ulceration of blebs.

Pressure sore.

Several superficial infections in open reduction cases but few impaired the final result.

One malunion, requiring open reduction.

Traumatic myositis ossificans (case of fracture of head of radius, olecranon and ulna shaft).

Dermatitis beneath an unpadded cast.

One non union of both bones, middle third, following closed reduction.

Ulnar and median nerve palsy (noted before reduction) with fracture of the neck of the radius and posterior dislocation at elbow.

Ulnar nerve palsy coincident with fracture of the olecranon coronoid and head of the radius.

Roentgenograms: Films showing two views should always be taken of every suspected fracture before an attempt is made to reduce it. This both reduces the possibility of trauma and protects the surgeon against the accusation of injury influenced

by his manipulation. After the reduction of a fracture under an anesthetic, the roentgenogram should not be taken until the anesthetic has ceased to act. Many times a fracture will remain reduced with the muscles still under the anesthetic but the fragments will slip when the muscle tension has returned. We had best be satisfied with the fluoroscopic evidence for that day and take a film twenty-four hours later. A third film, two views, should be taken two weeks later.

Physical therapy: A fracture recovers best when the nutrition of the bone and those structures associated with it most nearly approach normal. It has been our experience that the patient himself is his best physical therapist. It should be explained to him that return to function is his job, that only by exercise, supplemented by massage and heat, can he get well. He should be carefully instructed in how to use all of these measures. Aided active motion should be explained to him. Pain is nature's warning of trouble. He will not injure himself—a physical therapist might. If a therapist is on the case, at once the patient transfers all responsibility to his shoulders, feeling that he, only a patient, does not know enough to conduct his own treatment. The individual is his best physical therapist even without the various baths, rays, lights, currents, etc.

Whenever possible, active use should be started immediately after applying a cast.

Termination of fixation: Support should be used until there is clinical evidence of firm union. The existence or non-existence of firm callus as shown by roentgenogram is not dependable. Ofttimes union is solid long before the radiologist will commit himself.

Responsibility: Function necessary for the patient's livelihood is the aim in all fracture treatment. A surgeon treating fractures must be willing at least to supervise the case throughout. Treatment should be absolutely, entirely and constantly under the guidance of one individual.

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THE COLLES-POUTEAU FRACTURE OF THE LOWER END OF THE RADIUS*

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INTRODUCTION

ABOUT one hundred and twenty-five years ago Abraham Colles,[1] an eminent Dublin surgeon, described in very accurate detail a fracture of the lower end of the radius which occurs as the result of a fall upon the outstretched hand. Until the latter part of the eighteenth century this typical fracture had apparently not been recognized; the lesion had been presumed to be, and described as, a dislocation of the wrist. In 1783, Claude Pouteau[2] of l'Hotel Dieu, Lyons, first described the lesion. His contribution attained, however, but little recognition and when Colles drew attention to the fracture he believed that he was describing a lesion hitherto unrecorded.

In France, Dupuytren taught the frequency of the fracture and, at the same time, the rarity of dislocation of the wrist. In 1842, Velpeau drew attention to the characteristic deformity and suggested the term "dinner fork."

It is rather remarkable that an article by a surgeon of the importance and eminence of Abraham Colles should have made so little impression upon the surgical world of his time. It remained for R. W. Smith, another Dublin surgeon (who published a "Treatise on Fractures in the Vicinity of the Joints," in 1847) to draw again this matter to the fore. Incidentally, Smith described the characteristic triple displacement of the lower fragment. His contribution was also notable in that he described the rare type of fracture which now is known by his name, in which the lower fragment is displaced forwards.

Two further contributions, published during the next twenty years by Irish surgeons (E. H. Bennett of Dublin, and Alexander Gordon of Belfast), added considerably to an adequate appreciation of the importance of this injury.

In 1885, Robert Jones—then a young man practising surgery in Liverpool—presented an analysis of 105 cases of Colles's fracture treated by himself. It may be said that, with reference to the treatment of this condition, nothing was added to Jones's early contribution until very recent years, and even to-day it is probably true to say that the use of the metal gutter splints as advocated by him are more suitable for employment by the surgeon who only occasionally treats fractures.

CLASSIFICATION

In 1923, Étienne Destot,[3] of Lyons, published a monograph upon, and suggested a simple and useful classification of, fractures of the lower end of the radius. His classification divided these fractures into two main groups:

1. Anterior fractures which included three distinct types of injury: (a) fractures of the radial styloid process (Hutchinson's fracture); (b) anterior marginal fractures (reversed Barton's); and (c) the so-called Colles's fracture reversed, or Smith's fracture.

2. Posterior fractures which consist of: (a) classical Colles's or Pouteau-Colles's fractures; and (b) the posterior marginal fracture (Barton's).

In this contribution the typical Colles-Pouteau fracture only will receive detailed consideration, although towards the end of the article the reversed injury will also be discussed.

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Mechanism of Production. "It is well to keep clearly in mind that Colles's fracture is ordinarily a fracture-luxation of radius and ulna about the ulnar head as a fixed point; a rotary displacement in which the hand and the lower radial fragment are driven backward to be sure, but are more particularly rotated backward about the ulnar head." (Cotton.)

The typical Colles's fracture is the result of a fall upon the outstretched hand —the automatic movement carried out by the victim when he or she slips and falls. The two chief reasons for such falls in this latitude are icy pavements and hardwood floors, especially if the latter are furnished with Persian rugs. The importance of the former is well illustrated by the fact that in the Outdoor Department of our Western Division alone fifty-four cases were treated during January, 1937. During one particularly trying weekend during that month our newspapers reported that 200 broken wrists had been treated in the Montreal hospitals.

In order that a Colles-Pouteau fracture

Fig. 1. A. J. P., aged 11 years. Fracture of the lower end of both bones in the ultimate and penultimate fifths. In this type of injury the importance of the bending strain is exemplified.

may be properly reduced and the best possible end-result obtained, it is necessary, I believe, that the exact mechanism of production be clearly understood. Manifestly, there is (a) *compression in the long axis* of the radius, the force being transmitted through the carpal bones, in the dorsiflexed position, to the articular surface of the radius. Since the typical fracture only occurs in consequence of falls upon the outstretched hand, a (b) *bending* force is present, the compression aspect of the bend being on the dorsal surface of the bone and the tension aspect on the volar surface. Since the hand is fixed upon the ground and the body weight is transmitted through the forearm toward the ulnar border of the wrist, (c) *radial displacement* (abduction) of the hand, carpus and terminal fragment of the

radius occurs. Thus, also, may take place fracture, by tearing or arrachement, of the styloid of the ulna or rupture of the internal lateral ligament of the wrist-joint.

With the hand fixed to the floor in relative supination, as the body falls forward it transmits its weight through the forearm and forces the latter into complete pronation. It is thus evident that an essential, and in our opinion the most important, deformity characterizing the typical Colles-Pouteau fracture, is one of (d) *rotation* of the lower fragment. This rotation is, as indicated, one of relative supination of the lower fragment of the radius upon the pronated shaft of the bone.

That in certain cases of falls upon the outstretched hand the bending and compression mechanisms are of relatively more importance, and that in others the rotation of the lower fragment is almost the exclusive mechanism, is indicated by roentgenological examination of fractures of the lower end of the radius in children.

As is well known, Colles's fractures occur only very rarely in children. Instead of the typical fracture, such as is seen in the adult, we meet with either one or other of two separate and distinct lesions. In those cases in which compression and bending are of most importance, fracture of both radius and ulna at, or about, the junction of the ultimate and penultimate fifths of the bones occurs. In those cases in which rotation is of paramount importance, slipping of the epiphysis takes place. That in even these cases bending is also operative, is evidenced by the fact that almost invariably a portion of the diaphysis on the dorsal surface of the bone is squeezed off backward and remains attached to the epiphysis. That the latter injury is due to twisting is evident from stereoscopic *x*-ray films and, also, since reduction is most easily, most surely, and most permanently accomplished by simple rotation inward (pronation) of the hand.

In consequence of the combined compression in the long axis, and in consequence of bending and torsion strains, a definite (e) *grinding of the bone* on the dorsal surface occurs at the line of fracture. An appreciation of this definite destruction or pulverization of the bone is of the utmost importance if, in severe cases, an approximately normal replacement of the fragments is to be obtained.

Radiographic Findings. The typical deformity, as seen radiologically, in a case of moderate severity is as follows. In the antero-posterior picture, a *transverse fracture line* is to be noted approximately one-half to three-fourths of an inch (1–2 cm.) above the lower end of the radius. This line commonly *invades the radio-ulnar joint.* As a variant, the line may run definitely outward and upward. *Shortening of the radius* is evident since, whereas the styloid of the radius is normally about three-eighths of an inch (1.0 cm.) below the styloid of the ulna, in Colles's fractures the two styloids are likely to be at the same level, or occasionally the lower end of the ulna projects beyond the radial styloid.

In the lateral picture the most striking feature is the fact that, whereas the articular surface of the lower end of the radius is normally placed at an angle of about 105° to the long axis of the shaft, that is to say inclined approximately 15° toward the volar surface from the perpendicular, in Colles's fractures this surface is *inclined backward* toward the dorsal surface so that an angle of 90°, 80°, or even 70° is produced. The fracture line is seen to run downward and forward.

Commonly the small lower fragment appears to be *displaced* directly *backward.* Although backward displacement of the lower fragment is almost universally believed to be true, it is nevertheless not difficult to prove, I believe, that the apparent displacement backward of the lower fragment is, in fact, due to forward projection of the lower end of the shaft of the radius and that this in turn occurs in consequence of marked pronation of the forearm. The view that the backward displacement of the lower fragment is more apparent than real is supported, I believe,

by close examination of the *x*-ray films, when it will be noted that the lower end of the radial shaft appears to be displaced forward, due to pronation, and that the apparent displacement backward of the lower fragment is relative only.

Fig. 2. A. H., aged 12 years. Separation of the epiphysis at the lower end of the radius. It will be noted that in the lateral picture, the relationship of the epiphysis of the radius to the ulna is substantially normal. The forward displacement (due to pronation of the lower end of the shaft of the radius) is clearly shown.

Not infrequently the fact of *grinding* of the bone in the neighbourhood of the dorsal line of fracture is evidenced by the presence of many small granules or spicules.

DIAGNOSIS

Although Colles's fracture is a type of injury that is traditionally met with in elderly women,* it is, as a matter of fact, common in both sexes and throughout all periods of adult life. Crepitus in the diagnosis of the fracture is not useful, nor is abnormal mobility present, except in rare instances. Relative or complete loss of function of the member, pain and exquisite localized tenderness are invariable. Swelling is the rule and may be present to such a degree that it is difficult to note bony deformity by either palpation or inspection. Immediate swelling is due to hematoma formation.

In the well marked case, in which the "dinner fork" deformity is present, no difficulty arises in diagnosis. The case, however, in which comparatively little deformity of any sort is exhibited but in which the presence of a history of typical trauma is followed by relative loss of function of the member, represents a more difficult problem.

Although dislocation of the wrist does occur,[4] and although subluxation of the wrist, with consequent sprain, is a possibility, both of these phenomena are rare. The diagnosis of sprained wrist should, in the author's opinion, never be made without radiological proof that no fracture or dislocation is present.

* Of interest in this respect, as well as in other injuries and diseases said to be more common in elderly women, is the fact that among the old people in our communities the females far outnumber the males.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis of Colles's fracture brings into consideration the variants of the Colles's fracture already referred to in Destot's classification and, in addition, injuries to the carpal bones. It is not the author's intention in this contribution to discuss carpal injuries nor their treatment except to draw attention to the fact that fractures of the scaphoid and dislocations of the semilunar bone are not unusual injuries. Although a slightly different mechanism is required to produce the carpal injury, it is not always possible to differentiate from the patient's story exactly what mechanism may have been operative. In this connection I wish again to insist that a diagnosis of simple sprain of the wrist must never be made until after bone injury has been proven to be absent by adequate* *x*-ray examination.

Since the substantial disappearance of the "T-model" from our roads, the so-called "chauffeur's fracture" has largely ceased to visit our clinics. These fractures differ from the Colles's in that, if the fracture of the radius is transverse, it is closer to the articular surface than in the Colles's and is even more commonly simply one of splitting away of the radial styloid. These fractures are characteristically accompanied by but little displacement and rarely by comminution. With rare exceptions, their treatment presents few difficulties.

Fig. 3. Mrs. H. H., aged 46 years. This print shows typical displacement of moderate severity. Note involvement of radio-ulnar joint in fracture line and marked tilting backward of the lower fragment of the radius. Note also that the styloid processes of the ulna and radius are on the same horizontal plane. The soft tissue shadow in the lateral picture shows "dinner fork" deformity.

TREATMENT

Reduction. The reduction of a Colles's fracture is most surely accomplished, I believe, by the following procedure. If the injured forearm be grasped by the corresponding hand of the operator, the injured hand is grasped by the operator's other hand and traction employed. If the operator's knee* be employed to steady the injured forearm, the following maneuvres are, I believe, more easily carried out. It is usually advisable, especially in those cases exhibiting marked deformity, to gently in-

* Fractures of the carpal scaphoid (navicular) are very frequently difficult to demonstrate in either true lateral or anteroposterior pictures—if in doubt as to presence of a lesion oblique views should be made.

* The foot being placed on a stool.

crease the deformity present. This is done by bending the lower fragment backward and, at the same time, twisting it into supination. Disimpactation having been thus brought about, and the lower fragment loosened from the shaft of the radius, traction is continued upon the hand. The hand and consequently the carpus and lower end of the radius, are then twisted slowly into full pronation. Owing to the direction of the fracture line,—namely, downward and forward—it is impossible to force the lower fragment beyond, or forward to, the lower end of the upper fragment. When this has been done, it will be evident that the major part of the deformity has been corrected, although it is probable that palpation of the two styloids, radial and ulnar, will prove slight shortening of the former to be still present.

While traction and the pronated position of the hand are still maintained, the latter is bent over to the ulnar side so far as it can be made to go. In this way the ulnar styloid is placed in position and, moreover, such radial deflection of the lower end of the radius as has persisted following pronation, is overcome.

After pronation and ulnar deflection have been accomplished, flexion of the wrist-joint is somewhat forcibly but gently brought about. If the previous manipulations have been properly executed, flexion is possible through but a few degrees only, since the carpus will quickly impinge upon the lower end of the ulna. Forcible flexion is, however, necessary if complete length of the radius is to be re-established and, also, if normal deflection of the articular surface of the radius is to be brought about. The effect produced by flexion at the wrist-joint, with the hand in a position of pronation and ulnar deflection, is that using the hand as a lever and the lower end of the ulna as a fulcrum, traction is exerted through the dorsal capsular ligament of the wrist-joint upon the lower fragment of the radius. In this way it is possible so to draw down the lower fragment that a space actually exists between the cortical bone fragments on the dorsal surface of the radius. This bone free wedge-shaped area represents that portion of the bone destroyed

Fig. 4. Miss M. M., aged 57 years. Anteroposterior picture showing fracture of the lower end of the radius, avulsion of ulnar styloid, and tearing off of ulnar surface of the radius at the site of the inferior radio-ulnar joint.

by the grinding process. Unless such flexion is employed the lower fragment must tilt back until it finds support.

As a check upon the adequacy of replacement, palpation of the two styloids is of the utmost importance. Effective reduction is also indicated by a restoration of a normal anterior curve of the lower end of the radius. It must be realized that if the backward rotation and bending is completely corrected, the lower articular surface of the radius once more shows an inclination forwards as well as downwards.

To sum up, therefore, the manipulative procedure indicated, they may be tabulated as follows:

(a) *Disimpaction*—Traction, dorsiflexion, supination.
(b) *Traction.*
(c) *Pronation.*
(d) *Ulnar deflection.*
(e) *Flexion.*

It should be noted that (c), (d) and (e) employ the lower end of the ulna as a fulcrum, or pivot, around which the movements of the hand and carpus take place.

ANESTHETIC

The induction of anesthesia is necessary for adequate reduction. Nitrous oxide and oxygen will suffice in nearly all cases, as will of course such drugs as bring about more profound relaxation, such as cyclopropane and ether. Evipan has been employed in our clinic but has been largely given up—not however on account of untoward incidents. Local anesthesia, as popularized by Böhler, we have found very satisfactory.

If the skin over the dorsum of the wrist in the neighbourhood of the fracture, and over the ulnar styloid, be infiltrated over a small area by means of a fine needle with 2 per cent novocaine, a larger needle can then be inserted through the anesthetized skin down to the fracture line. By withdrawing the plunger, blood from the hematoma about the fracture is withdrawn into the syringe; proof is thus obtained that the space about the fracture has, in fact, been entered. At the same time, it is usually comparatively easy to palpate with the point of the needle the fracture line itself. About 20 c.cm. of 2 per cent novocaine is slowly injected into the hematoma surrounding the fracture of the radius and through a separate puncture, about 8 c.cm. of a similar solution in the neighbourhood of the ulnar styloid.

If patience be exercised and no interference made for a period of five minutes following introduction of the local anesthetic, it will be found possible to carry out whatever manipulation is necessary, with little or no discomfort to the patient, and with adequate relaxation.

FIXATION

After reduction of the fracture, the method of fixation to be employed is dependent, in large measure, upon the familiarity of the surgeon with the application of circular plasters. For employment by the surgeon who has become thoroughly familiar with such technique, the application of a circular plaster from the middle and upper thirds of the forearm to the base of the metacarpal heads, will result, I believe, in the best possible ultimate result and also with a shortening of the period of disability.

In the application of a circular cast the forearm and hand are covered with a thin layer of sheet wadding. Over this plaster of Paris is carefully applied. The plaster bandage must be laid on evenly and without tension, the hand being maintained in its position of pronation, ulnar deflection, and flexion during application of the plaster. One or one and one half 4 inch bandages suffice for the normal adult forearm and hand. A heavy plaster is not necessary since its function is to maintain the pronated, adducted, flexed position of the wrist, rather than to splint the fracture line.

If the surgeon be not thoroughly familiar with the application of circular plaster casts, it is advisable, I believe, for him to employ plaster splints. For this purpose a 4 inch plaster bandage is arranged as a moulded splint, approximately eight thicknesses being employed, the splint being sufficiently long to reach from the junction of the middle and upper thirds of the forearm to the base of the metacarpal heads. A thin layer of padding is placed over the forearm and hand, and the splint is laid over this, care being taken that it is so fashioned that pressure is made over the radial aspect of the first metacarpal. After moulding the splint carefully, it is fixed in position with a flannel, or flannellette, bandage, which must be carefully applied and which must not cause pressure at any point.

The "sugar-tongs" type of plaster splint has distinct merit and is to be recommended. The fact that the elbow-joint is largely immobilized, and that the rotary movements of the forearm are eliminated,

renders the patient more comfortable in some cases.

As previously indicated, although the employment of Sir Robert Jones'[5] technique will not, I believe, result in as perfect results being obtained, the employment of moulded metal gutter splints, as recommended by him, can be applied with less risk of circulatory disturbance, and with the expectation of a good result.

FIG. 5. Mrs. J. G., aged 55 years. Typical Colles' fracture with but moderate displacement. Tilting of lower fragment is clearly shown, as well as displacement forward of lower end of radial shaft. In the anteroposterior picture, involvement of the inferior radio-ulnar joint in the fracture line is shown.

EARLY POSTOPERATIVE CARE

No matter what method of fixation be employed, it is essential that the patient be kept under close observation for the first twenty-four to forty-eight hours following reduction. So soon as the plaster has set it should be trimmed so that there is no interference with movement of any of the fingers. The patient should be immediately able to fully dorsiflex the thumb actively, and in the majority of instances is able, and willing, to flex and extend the fingers through a moderately normal range.

Posture, obtained by elevation of the limb on pillows while in bed and the employment of a sling, with the hand at a higher level than the elbow, when ambulant, will minimize, in large measure, swelling of the fingers. The complaint of any considerable amount of pain, or the presence of more than a moderate amount of swelling of the fingers should be accepted as proving the necessity for interference with the cast. Such interference should consist in the division of the plaster along the ulnar border of the forearm, and in spreading of the cast. The author is convinced that the simple splitting of the cast, unless care be taken to be certain that it has been spread, is not only useless, but dangerous, since it is likely to lead to a feeling of security which is not justified. The day following reduction, passive hyperextension of the thumb and of all four fingers should be carried out to the maximum, even though a small amount of pain is suffered by the patient during this performance. If this procedure be post-

poned until a later date, it will be found less possible to bring about hyperextension and also that more pain will be suffered by the patient.

The patient is advised to carry out these passive movements twice daily. This is done in order that no opportunity should be given to the superficial and deep flexors to the fingers to become shortened, or fixed, during the period in which the wrist is flexed.

At the end of three to five days it is usually possible for the patient actively to flex and extend the fingers through an approximately normal range of movement. In the long run it is better to see the patient at least every third day during the first ten days following injury, in order that, on the one hand the appearance of the limb may be checked and the patient's history noted as to comfort or discomfort, and on the other hand in order that the surgeon may be certain that hyperextension of the fingers is in fact being carried out. At the same time, the patient is urged to carry out active movements himself.

The advantage of the closely fitting circular plaster over moulded plasters or splints is that fixation of the fragments being more surely established, the patient is more willing and able to carry out both the passive and active movements than would otherwise be the case.

Since it may be presumed that sufficient stability of the new tissue—which will fill the wedge-shaped space between the bone fragments—will not be attained in less than ten days, it is inadvisable, I believe, to remove the first plaster before the tenth day, on the other hand it should be removed by the fourteenth to eighteenth day, since if the flexed and pronated position be maintained for a longer period, difficulty may be later encountered in bringing about dorsiflexion of the wrist. I believe, however, that the risk of such a deformity has been greatly exaggerated.

When the plaster is removed, the hand is placed on a pillow so adjusted that pronation and flexion at the wrist are maintained. Gentle stroking of the hand, carpus and forearm are employed, in part, in order to gain the patient's confidence. He is then asked actively to flex and extend the wrist-joint. At this stage it will usually be found possible for him to carry out flexion more or less completely, and dorsiflexion to an angle of about 110° without discomfort. This fact may be taken as proof that the fracture line has become stabilized and that no dead space exists between the bone ends. Diathermy may well, I believe, be employed at this time.

Plaster of Paris in the form of a cast is then reapplied, either directly on the skin or over a single layer of crêpe bandage. During the application of this cast the patient is instructed to dorsiflex the wrist himself, so far as is possible without discomfort. At the same time, the position of exaggerated pronation is modified by about one-half. Again care is taken that no interference with function of the fingers results from the application of this cast.

With such a snugly fitting plaster supporting the fracture line and wrist-joint, it should be possible for the patient to engage in many activities, nor need any prohibitions be insisted upon, other than the simple one of instructing the patient to refrain from activities which cause more than a slight amount of pain. If he plays the piano, it is advisable for him to commence at this time. The patient should use table utensils and may well commence knitting or crocheting. Very frequently he is able to commence driving a car at this time.

After the first change of plaster, the patient should be seen at weekly or ten day intervals, and at each of these visits the plaster may be removed and gentle massage carried out, active movements at the wrist and carpal joints permitted and diathermy employed. The plaster is again applied as at the second application—that is, without padding.

In the author's opinion, it is advisable to maintain fixation by plaster for a period

of approximately six weeks from the date of accident. This is longer than usually recommended. I am convinced, however, that in the long run a full return of function is hastened by more prolonged fixation, with consequent ability to carry out active duties.

Fig. 6. Miss G. N., aged 49 years. Lateral *x*-ray following reduction. Note loss of bone substance towards dorsum of radius at site of fracture, reestablishment of inclination of articular surface towards palm, and relative position of radius and ulna.

CONVALESCENT TREATMENT

When the plaster is finally removed, approximately six weeks after injury, it is to be expected that there will be but little interference with function of the fingers or thumb. Movements of the wrist-joint, also, are usually substantially normal. Pronation is usually complete, although supination will be only about one-half normal. I make a practice of advising the patient early, that complete return of the rotary movements of the forearm will be the last function to be regained.

If no complications have arisen and if co-operation on the part of the patient has been obtained, I believe reasonably normal function of the extremity should be manifest at the completion of from three to four months following injury. During the six to ten week's period following removal of the plaster, the amount of oversight required will depend, in large measure, upon the individual case. The patient is instructed to use hot bathing in physiologic salt solution at home twice daily, and to return for diathermy, and oversight, one to three times weekly. He is advised to carry out all activities which are not associated by pain of more than a mild degree. At the same time he is told that it is unwise to attempt, in any way, to force movements, more especially the rotary movement.

PERIOD OF TOTAL DISABILITY

Granted adequate reduction and treatment, the period of total disability which will be suffered by the patient will depend, in the first place, upon the nature of the work which the hand is called upon to do, in the second place upon the severity of the original injury, and in the third place upon the intelligence of, and co-operation displayed by, him. As a rule, the housewife or domestic servant is able to undertake such duties as sweeping, dusting and the making of beds as soon as the second plaster has been applied—namely, ten to twelve days following injury—although not infrequently a patient reports that she has

been able to carry out such duties by the third or fourth day. A labouring man, on the other hand, should be considered to be totally disabled, I believe, as a rule, for a period of approximately four months from the date of accident.

Permanent Partial Disability. In the majority of cases of moderate, or less, severity, the permanent disability suffered by the patient is theoretic rather than real. I am of the opinion, however, that no patient should be presumed to have no permanent partial disability, who has in fact suffered a fracture of a large bone such as the radius. In my opinion, such theoretic disability is reasonably estimated as being in the neighbourhood of 3 to 5 per cent. If, however, as the result of the severity of the original injury, delay in reduction, inadequacy of reduction, inadequacy of post-operative treatment, or a combination of the factors, there is, in fact, real interference with the function of the radiocarpal, radio-ulnar joints, or free movements of the tendons, each case will have to be judged upon its merits. Deformity alone is not necessarily an important cause of disability, unless it be so marked that subluxation of the ulna occur.

REVERSED COLLES-SMITH'S FRACTURE

The reversed type of fracture is fortunately rare, since the usual results of treatment are disappointing. It is of the utmost importance that these cases be recognized. Clinically they may be suspected, but for their diagnosis true lateral *x*-ray photographs of the wrist region must be obtained. They occur as the result of a fall upon the flexed wrist. In consequence, the typical deformity is one of exaggerated pronation of the lower fragment and hand, and apparent forward tilting of the lower fragment. It is accompanied by a fracture line which runs forward and upward.

Having, in the last paragraph, indicated the mechanism of production and the deformity present in the reversed type of injury, the method of correction of the deformity seems evident. After having broken up whatever impactation be present, the hand and lower fragment, or fragments, are forced into full supination. It is, I believe, impossible to exaggerate this movement. While pressure is exerted with the heel of the hand over the volar surface of the lower part of the radius, the wrist is placed in moderate, to marked, dorsiflexion. At the same time, adduction of the hand is brought about.

Since the maintenance of supination in these cases is of such paramount importance, it is advisable, I believe, so to apply the plaster-of-Paris retention apparatus that the elbow-joint is also fixed. Plaster of Paris is consequently applied from the middle and upper border of the arm to the base of the metacarpal heads.

CONCOMITANT INJURIES

Since a Colles's fracture is due to a fall upon the outstretched hand, it is possible that other injuries of the upper extremity, due to the same cause, may also be present. In this category may be mentioned fractures of the lower end of the humerus, of the surgical neck of the same bone and dislocation of the shoulder-joint—also, posterior dislocation of the elbow.

In my experience, approximately one-third of all patients who suffer from Colles' fracture have, as the result of the same injury, experienced contusions of the subacromial bursa or injuries to the supraspinatous tendon. A painful shoulder is in consequence very frequently complained of, not, as a rule, during the first few days following the accident but, more particularly, after return of function of the upper extremity, as a whole, is attempted. I have made it a practice, therefore, to inform patients that this complication is likely to be noted, so that when the painful shoulder is, in fact, experienced, the patient is not surprised. Fortunately, the period of rest required for complete return of function of the hand usually suffices to accomplish repair of the bursal injury.

COMPLICATIONS

Compounding of Fracture. The most obvious complication, regarding the treatment of which nothing will be said in this contribution,[6] is that of compounding. It is unusual and is present only, I believe, as the result of street accidents and falls from a height.

Median Nerve Injury. Apart from compounding, the most serious early complication, in my opinion, is that of median nerve injury. In a (fortunately small) percentage of cases the median nerve is bruised by the lower end of the upper fragment and kinked at the site of bending. Under these conditions the patients may suffer extreme pain which is referred to that part of the hand supplied by the median nerve. Large doses of opiates may be required for its control.

Characteristically the most severe pain is not experienced in the first hours following injury, but is likely to become most severe twenty-four to thirty-six hours later. It is impossible, I believe, to indicate in the individual case how long the condition will last, although it may be confidently expected that the pain will become mitigated within a few days and that ultimately there will be recovery, although this may take several months.

Parathesia, or loss of sensation, in the thumb, index, and mid fingers is exhibited. I have not seen, nor noted record of, a case in which either causalgic pain or loss of sensation persisted permanently.

When the condition is exhibited, the patient, I believe, should be considered one for hospitalization. The plaster cast should be bivalved, so that it may be removed for purposes of baking and very gentle massage. Immersion in hot water is likely to be followed by relief to the patient. Under these conditions, the fracture itself requires very careful protection while out of its splints.

Ischemic Paralysis. Volkmann's ischemic paralysis has been known to occur in the course of treatment of a Colles's fracture; it is much less common, however, in these cases than in fractures of the middle third of both bones of the forearm. At the same time, since the substitution of plaster of Paris for wooden splints has been made in most clinics, the incidence of this very serious sequel has been largely eliminated. The most certain prophylactic is, in my opinion, early adequate reduction and fixation.

Acute Bone Atrophy (Sudeck's Atrophy). An unfortunate development in a small percentage of cases is that of acute bone atrophy.[7] This condition of "patchy" absorption of calcareous material from the bones of the fingers, hand, carpus and lower end of the radius represents a definite entity having apparently a characteristic etiology and running a definite clinical course.

It develops, apparently, only in cases which have been either inadequately protected or in which repeated insult, by two or more attempts at reduction, has been inflicted. Clinically, the condition is, I believe, readily diagnosed. As a rule, it makes its appearance approximately three weeks, or less, following injury. Fingers, hand, wrist-joint region and lower part of the forearm become swollen and somewhat engorged in appearance. Movements of the fingers, which may previously have been reasonably free, become relatively impossible and both active and passive movements are very painful. Movements of the wrist become well-nigh impossible on account of pain, and the rotary movement may be completely lost.

Of the utmost importance is it that the hand, forearm and wrist be protected from further insult. Attempts to use the limb should be discontinued until these again become painless. Diathermy would appear to be a satisfactory method of treatment, although so long as no pain be inflicted it is evident that other forms of physiotherapy or massage are helpful.

The danger of Sudeck's atrophy ensuing must be borne in mind in estimating the usefulness of attempting correction of a

mild degree of deformity a few days after reduction. Repeated manipulation should be attempted only if judged to be absolutely necessary.

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"Joint injuries as complications of fractures fall into two groups—those in which the fracture line communicates with the joint and those in which it does not. Either type of joint injury may result in a traumatic arthritis."

"Pneumonia and embolism are the two types of pulmonary complications met with after fractures. Embolism is relatively rare. . . . Pneumonia after fractures occurs most frequently in aged and debilitated patients, and especially in those the nature of whose injury necessitates immobilization in bed in recumbency."

FRACTURES OF THE CARPAL BONES

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THE subject of carpal bone fractures has assumed a position of importance in the consideration of all men who treat fractures. The navicular (scaphoid) is the most commonly fractured bone in the carpus, and it stands third in fracture incidence among all bones distal to the radius and ulna, being preceded only by the phalanges and the metacarpals in the order named. The undiagnosed or improperly treated fracture of the carpal scaphoid may become an economic tragedy in the life of the patient who earns his living with his hands.

The following figures from the files of the *x*-ray Department of the Episcopal Hospital, covering the period from Jan. 1, 1931, to June 15, 1937, demonstrate the relative frequency of carpal fractures:

Navicular (scaphoid)	144
Lunate (semilunar)	11
Triangular (triquetum or cuneiform)	7
Pisiform	1
Greater multangular (trapezium)	3
Lesser multangular (trapezoid)	1
Capitate (os magnum)	2
Hamate (unciform)	1

There were eleven unidentified carpal fractures in which the source of the small chip fragment could not be definitely determined.

These figures not only show that the scaphoid is the most commonly fractured bone in the carpus, but also that fractures in the carpus with but few exceptions occur in the most mobile bones; i.e., in the proximal row except the pisiform (which is sesamoid in the flexor carpi ulnaris tendon), and in the greater multangular at the base of the first metacarpal. This should be borne in mind while reviewing the anatomy.

PATHOLOGICAL ANATOMY

The carpal scaphoid occupies about two-fifths of the radial side of the proximal carpal row. The bone is narrowest at the middle and across this narrow dorsal surface is attached the dorsal carpal ligament through which blood vessels enter the bone. The distal surface possesses a distinct tubercle projecting volarly, on which the transverse carpal ligament finds part of its attachment. Its middle is probably the weakest point in the proximal row of carpal bones for three reasons: first, it is thinnest in its middle; second, the cortex, which is the only hard bone found in any of the carpals (the interior being cancellous), is perforated by small vessels on the dorsal middle surface; and third, the scaphoid is not segmented as are the osseous elements of the proximal row on the ulnar side of the carpus, and so is subject to more strain.

The transverse fracture in the middle of the bone is by far the most common, (73 in 107) and next in frequency is the distal end of the bone including the tubercle (7 in 107), followed by a small percentage in the proximal end (2 in 107), and along the posterior border (2 in 107). The exceptional fracture may be comminuted (4 in 107). Fragments when displaced invariably move in a volar direction. Rarely does the bone sustain more than one separate fracture, and when this occurs (2 in 107), one fracture line is the usual transverse type through the middle, and the other is likely to be in the distal end.

The semilunar is the keystone of the arch formed by the proximal row, and is subject to chip fracture, fracture through the body of the bone, and possibly a moderate crush

fracture, the effects of which may not show in early *x*-rays. It is the most commonly dislocated bone in the carpus.

FUNCTIONAL ANATOMY

Knavel, in his monumental work on infections of the hand, not only crystallized his large experience with these cases for the profession, but with the support of a surgical organization and by use of moving pictures, he popularized new concepts of anatomy based on painstaking laboratory work. A similar worthwhile task awaits performance in the popularizing of the functional anatomy of the hand and wrist; to show how force, instead of infection, is received in the hand; how it travels, is disseminated and what toll it takes of the structures in its path; how it affects, in a routine manner, the structures which are mechanically weak.* This knowledge should be widely diffused in the profession, appropriately beginning with a moving picture in the medical school, similar to that used in teaching infections of the hand. The standard anatomical texts are not very helpful in this respect.

It is well known that the man doing general work is the first to see fractures of the carpus, as he is the first to see infections of the hand, in the great majority of cases. Such a patient does not call for a trained surgeon when he first decides to seek professional advice. But this period is a very important one in these cases, and represents a splendid opportunity for the alert man doing general work. A knowledge of the anatomy of the hand and carpus is not difficult to grasp or retain if properly considered, and it is a prerequisite if one is to understand the incidence, location and treatment of these fractures. Figures 1 to 5, with the accompanying legends, illustrate the fundamental points.

*A fine example of correlating a knowledge of applied anatomy with the known incidence of certain fractures, in demonstrating the direction and dissemination of force in the body, is seen in the classification of ankle fractures worked out by the late A. P. C. Ashhurst, with the aid of E. T. Crossan and R. S. Bromer.

For teaching purposes and for accurate clinical work, it is well to divide the hand and carpus into the three following portions, each of which moves as a unit:

1. The proximal row of carpal bones. This unit may be regarded as an intercalated disc between the bones of the distal row and the radius; somewhat in the nature of a universal joint. It serves as an adjustment plate in the transmission of force between the distal carpal row and the radius. Figures 3 and 5 demonstrate the manner in which the proximal carpal row rides like a stirrup over the distal row as the hand goes into dorsal flexion. The radial and ulnar ends of this stirrup are formed respectively by the scaphoid, and by the triangular with the superimposed pisiform.

2. All the metacarpals except the first, and all the bones of the distal carpal row except the greater multangular. This is the central unit of the hand, into which the flexor and extensor tendons of the wrist insert. Between the bones of this unit, which is circumscribed by the line drawn in Figures 1 and 2, there is no movement. The four metacarpals and the bones of the distal carpal row, except for the greater multangular, are tightly bound together by strong ligaments. Likewise, the three distal carpal bones are bound to each other, making a firm unit for all clinical purposes, composed of members which have very slight, if any, individual motion. Attention was called to this fact in 1933,[1] and Walmsley[3] in his second edition (1934) has written, page 219; "The metacarpal bones are to be considered as fixed to the distal row of carpal bones and to move with them."

3. The first metacarpal with the greater multangular. The thumb is freely movable in its saddle joint on the greater multangular, which in turn is freely movable.

Walmsley[3] states, page 218; "The carpal bones are bound together in two rows, so that while only slight adaptional movements can occur between those in each row a considerable amount of movement is possible between the two rows. . . . The

mid-carpal joint between the two rows is a double ball-and-socket joint. The proximal surface of the distal row has a central 'head' formed by the capitate and hamate bones, which fits into a socket formed by the scaphoid, lunate, and triquetal bones, and the scaphoid forms a 'head' which is received into a concavity formed by the trapezium and trapezoid bones."

Attention has been drawn to the fact that all the powerful flexors and extensors of the wrist have their insertions distal to the proximal row of bones, so that the proximal row may be said to move freely between the flexor and extensor tendons, but is controlled largely by the two main flexors of the wrist. This control is maintained by the attachment of the flexor carpi radialis tendon to the scaphoid in its fibro-osseous canal, on the radial side of the carpus, and also by virtue of the fact that the pisiform is sesamoid in the flexor carpi ulnaris tendon and is held in close contact with the triangular at all times, on the ulnar side of the carpus.

A probable mechanism of scaphoid fracture, centering about the carpal arch formed by the bones, was described in 1933.[1] The bases of this arch are formed on the thumb side by the distal end and tubercle of the scaphoid, and the ridges on the multangular bones; on the ulnar side by the pisiform held against the triangular, and the hamate process of the hamate bone, in the palm-down position. The strong transverse carpal ligament, connecting the bases of the arch, converts it into the carpal canal, through which pass the flexor tendons of the fingers and the median nerve, and prevents the bases of the arch from spreading apart when pressure is applied. At either base the arch rests on the flexor carpi radialis and on the flexor carpi ulnaris tendons. (Fig. 5.)

As dorsal flexion of the wrist increases, tension is developed in the flexor tendons, and increased force is applied to the bases of the arch. One notices here that the tension force in the flexor tendons, caused by dorsiflexion, contraction, or both, gives rise to a pressure force against the bases of the arch. This is a common occurrence in any pulley arrangement, such as found in this area, where the flexor tendons change direction sharply in passing under the carpus. The distal part of the carpus with the metacarpals is pulled downward toward the surface on which it rests, by the pull of these tendons at their insertion. The flexor tendons of the fingers help to support the middle of the arch.

When pressure is exerted on the arch by the radius in a fall on the hand, the bones tend to spread apart. This action is resisted by the transverse carpal ligament, with the result that the scaphoid bone, whose proximal end is held fixed against the radius by the semilunar and by the capitate, is fractured. The other common result is that the semilunar is forced directly downward into a volar dislocation. More rarely a combination of fracture dislocation occurs. After a consideration of the anatomy shown in Figure 5, the types of injury which one might predict as being most common clinically, are actually found to be so: these are, namely, fracture of the scaphoid and fracture or dislocation of the semilunar.

Obviously the semilunar is the keystone of this arch, and Kienboch's perilunate classification of carpal dislocations (which is well described in Speed's monograph page 82)[2] is superfluous.

DIAGNOSIS

The patient with a recent fracture of the carpal scaphoid is more often male than female. Episcopal Hospital records show 228 males and 32 females in a series of 260 consecutive cases. His age will most commonly fall in the second, third, or fourth decade; exceptionally in the fifth or sixth, and rarely in the first. The brief history describes a sudden force received through the palm of the hand, with the hand in the dorsiflexed position. This force may be sustained in a fall on the hand, from the backfire of a motor, or in striking some object with the palm. There

is seldom a history of direct force, either a blow on the wrist or a crushing injury. The patient's chief complaint is often that of a "sprained wrist," and his usual symptoms are pain in the wrist joint on motion, and weakness in the gripping power of the hand.

A rigid examination is in order, and it should be especially thorough in those cases with minimal complaints. Examination reveals a wrist joint with little or no swelling, and with active motion present in all directions. Crepitus is ordinarily absent, and if present is so slight as to be distinguished with difficulty from a tendon rub. The power of the grip is usually weakened when compared to that of the other hand. Movement in the wrist is frequently painless within a certain range, but if the hand is forced into the extreme range of motion in any one direction, pain is usually elicited. This is especially true in forced dorsiflexion, and while this sign is not pathognomonic for fractured carpal scaphoid, its absence will rule out such a fracture, in the great majority of cases. The probable explanation for this is that in forced dorsiflexion the flexor tendons of the wrist force the bones of the proximal row together, causing pressure on the scaphoid or its fragments. The carpus is locked on the dorsal lip of the radius in full dorsiflexion.

Fig. 1. Direct anteroposterior view. Complete radial deviation, 180 degrees extension. The long axis of the third metacarpal is in line with the os capitate and with the semilunar bone. The scaphoid is viewed from the distal end of its long axis, causing an apparent shortening.

Fig. 2. Direct anteroposterior view. Complete ulnar deviation, 180 degrees extension. The long axis of the third metacarpal is in line with the os capitate, but not with the semilunar bone. Note that the pisiform bone moves only slightly off the triangular, in a proximal direction, with ulnar deviation. There is probably a small amount of scaphoid rotation about its transverse axis. Distortion, owing to the distance from the center of focus, must be considered.

In searching for tenderness, the examining thumb should exert pressure in the anatomical snuff box, and, if tenderness is found, one of four conditions may be suspected; first, fracture of the scaphoid; second, fracture of the tip of the radial styloid; third, fracture of the base of the radial styloid; and fourth, any combination of these three. Tenderness should now be sought on the volar surface of the wrist. There is to be seen in all wrists two transverse flexion creases in the skin on the volar surface. Speed[2] aptly called attention to the fact that the radial end of the proximal flexion crease is over the scaphoid and the joint line. Pressure should be applied with the thumb over this area, and suspicion of fracture is further increased if tenderness is found.

Fig. 3. Lateral view. Complete dorsiflexion, midposition. This view was taken while the subject placed all the body weight possible, short of losing his balance, on the hand.

The flexion creases of the wrist serve as excellent landmarks for this region and are valuable teaching aids. The majority of students when first introduced to this subject, with the patient before them for examination, will locate the scaphoid too far distally. It has been helpful to have them ink in on their own wrists, with an *x*-ray film at hand for comparison, the approximate position of the carpal bones on the volar surface, locating the distal end of the scaphoid in the snuff box with the hand in mid-position or radial deviation, and the proximal end and body of the bone under the proximal flexion crease. If one is able to locate accurately the position of a single bone in the carpus with relation to surface markings, he is then able to find any or all of the remainder.

Other surface markings are sometimes helpful. The pisiform bone may be found at the base of the hypothenar eminence, and may be grasped with the thumb and finger when the wrist is flexed, and moved from side to side. Distal to the pisiform and toward the middle of the hand may be found the hook on the hamate bone, but this is felt with difficulty except in thin hands. The tubercle of the scaphoid may be felt at the middle of the base of the thenar eminence, and, immediately distal to it, is found the crest or ridge of the trapezium. The transverse carpal ligament is attached to all four of these bones.

Certain conditions may be confused with fracture of the scaphoid, but fortunately most of them are identified by the roentgenologist. The dislocated semilunar may be palpated on the volar surface of the carpus, with a corresponding depression on the dorsal surface. Fracture of the semilunar is identified by tenderness over the bone, but actually the clinical differentiation is not as easily made as one might suppose. All bones of the proximal

row may be tender in some cases, as a result of the force received in the injury. It is difficult to approach the semilunar from two different directions as is possible in the case of the scaphoid. The dorsal lip of the radius overhangs it and, to overcome this, one may attempt palpation of the bone with the wrist held in volar flexion. As in the case of the scaphoid, forced hyperextension of the wrist, producing pain over the semilunar, has been the most valuable sign of fracture in the hands of the writer.

FIG. 4. Lateral view. Complete volar flexion, midposition.

Dorsal lip fracture of the radius (Barton's) may be identified by the fact that it usually extends completely across the radius. Suprastyloid (Colles') fracture, occurring more proximally in the radius, offers little difficulty. Fracture of the tip of the styloid, located as it is in the snuff box, will always offer some difficulty. Here is where the ability to approach the scaphoid in two planes is of use. If tenderness is present at the bottom of the snuff box, and not present over the proximal flexion skin crease on the volar surface, there is probably a fracture of the tip of the radial styloid. However, this diagnosis may be an error, owing to the fact that some part of the scaphoid is always at the level of the tip of the styloid, either with the wrist in full ulnar or radial deviation. (Figs. 1 and 2.)

A fracture at the base of the radial styloid may give tenderness when pressure is applied to the tip in the snuff box. This tenderness is caused by tilting of the entire styloid fragment, and the patient may not sharply localize the pain. Pressure over the proximal flexion crease on the volar surface does not help much in this case, for the usual transverse fracture line at the base of the radial styloid (Chauffeur's) ordinarily runs into the joint surface under the proximal flexion crease. Fractures at the base of the first metacarpal and of the multangulars are not often confused with fractures of the scaphoid. Pain in the wrist may be the complaint of the patient in whom one finds the crepitus of a tenosynovitis, usually in the extensor tendons. The absence of sudden injury and the occupation are clues to the correct diagnosis. Any combination of these conditions may be found in a single case, and all of these patients may give a strikingly similar history.

There remains a small group of patients who also give a history of a fall on the hand with pain in the wrist. One may or may not find tenderness in the snuff box, but there is often tenderness over the proximal volar flexion crease on the thumb side of the wrist. Forced hyperextension of the wrist will often be painful. These patients have been confidently sent for *x*-ray with

a diagnosis of scaphoid fracture, only to find a diagnostic error. Usually with one week of splinting on a straight board splint, complaint of residual pain on wrist motion, seems to confirm the diagnosis of acute traumatic tenosynovitis.

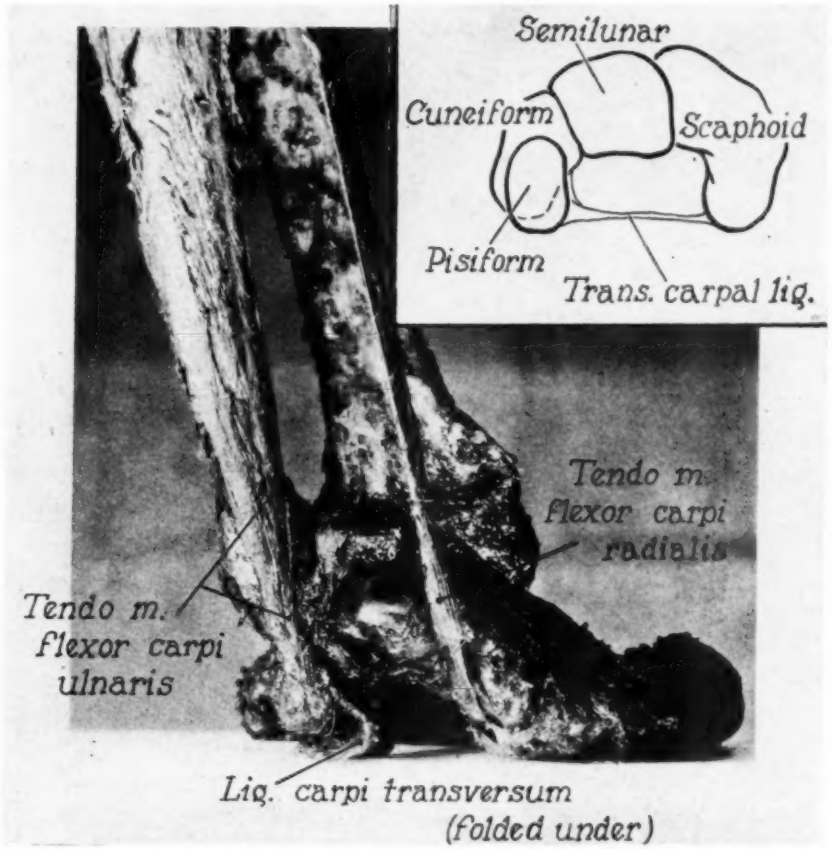

Fig. 5. Lateral view. Palm down position, as in a fall on the hand. The flexor tendons of the fingers, the median nerve, and the posterior capsule of the wrist joint have been removed. The usual anteroposterior views of the carpus, shown by *x*-ray in Figures 1 and 2, are very deceptive in regard to the true anatomic relationships. Roentgenologists who have the responsibility of silhouette review of bone anatomy in graduate or undergraduate instruction, would do well to have always at hand this or a similar view.

all symptoms and signs disappear. It has been assumed in these cases that the correct diagnosis was acute traumatic tenosynovitis of the flexor carpi radialis tendon. It was pointed out in 1933[1] that the flexor carpi radialis tendon lies directly against the volar surface of the tuberosity of the scaphoid, with its sheath considerably thickened at this point. Owing to this exposed position, the tendon and its sheath might easily sustain injury in any fall on the hand or in backfire force. The exceptional case of recent fracture in which check-up *x*-ray examination shows excellent bone union, but in which there is some

In this small last-named group, there is an occasional case which may be misdiagnosed by the roentgenologist, owing to the rush and hurry of a busy *x*-ray service, or to the difficulty inherent in reading the film. These are practical problems in a busy institution of any size. The wrist should be splinted on suspicion for the duration of pain and weakness. A check-up *x*-ray examination at the end of three weeks may show a thin line of callus in the suspected fracture area.

Fractures in other bones of the carpus are suspected by eliciting pain on pressure. The pisiform may be pressed upon and

moved from side to side. Tenderness here will lead one to suspect injury of the pisiform or triangular. Pressure over the crest of the trapezium at the base of the first metacarpal, or medially in the long axis of the thumb, may give fracture pain or tenderness. The remaining carpal bones are rarely fractured, and if so, the fragments are not easily displaced and heal promptly. Their fracture is often a matter of severe crushing injury. The rather numerous fractures occurring at the base of the first metacarpal is interesting, in view of the common escape from injury of the trapezium.

Finally, and of prime importance, is the *x*-ray examination of the wrist, taken in two planes and read by a competent roentgenologist. Any complaint of pain or weakness in the wrist following trauma should arouse suspicion, and should have the benefit of an *x*-ray examination at once. Modern knowledge of these fractures, with their inevitably poor results when improperly treated, points to the dismissal of a so-called "sprained wrist" without an *x*-ray examination, as an invitation to professional and medico-legal embarrassment.

The diagnosis of "sprained wrist" is an improper diagnosis, and might have been so recognized, even in pre-Roentgen days. The wrist is not a joint which is subject to sprain, and a true sprain in any way comparable to that of the ankle must be very rare indeed. The wrist, like other parts of the body, may be bruised or contused, and acute traumatic tenosynovitis may occur here. The rarity of true sprain is no doubt accounted for by the fact that the wrist joint is protected by joints proximal to it, which have greater ranges of motion than any other joints in the body. The wrist joint has radial and ulnar deviation of 25–30 degrees and 35–40 degrees respectively, when in full extension (180 degrees). This lateral motion decreases as the hand is dorsiflexed until in full dorsiflexion the ulnar and radial deviations are absent. But with the palm fixed on the ground, the humerus and ulna may rotate around the radius almost 180 degrees, while the humerus has 90 degrees rotation on its axis, in addition to 360 degrees circumduction in the shoulder. The flexion and extension hinge joint of the elbow protects the carpus against too great a degree of dorsiflexion when the force is received. The elbow has only to go into greater flexion, thereby lowering the proximal end of the radius, and so adjusting the dorsiflexed hand to receive the force. The summation of these anatomical facts clearly indicates that the hand is carried on a very adaptable pedestal.

ASSOCIATED INJURIES

Any of the conditions named in the differential diagnosis may be found associated with fracture of the carpal scaphoid. Most commonly these fractures are associated with dislocation and fracture of the semilunar bone, with fractures in the distal end and styloid of the radius, and with fractures of the head of the radius. Although fracture of the radial head associated with scaphoid fracture has not been especially frequent in our cases at the Episcopal Hospital, the combination deserves emphasis, owing to the likelihood that the radial head fracture may be missed, in taking only the usual small film of the wrist. Any finding of pain or tenderness referred to the head of the radius following a fall on the hand, should be an indication for *x*-ray examination of the elbow. The bad results of improperly treated fractured scaphoids are only to be compared with the poor results found in neglected radial head fractures.

Bipartite scaphoids may be suspected in a recent case if the edges of the fragments appear smooth and rounded off in the film. Films of the opposite wrist may show a similar condition. In case of doubt, and where there is much pain or weakness, a splint should be applied and continued from week to week until the pain and weakness disappear, or until a check-up *x*-ray examination reveals either callus formation or no change.

TREATMENT

Any recent fracture of the scaphoid bone of two weeks' duration or less, without separation of fragments, should be splinted routinely for five weeks. At the end of this period, clinical and check-up *x*-ray examinations will determine whether or not longer splinting is necessary. If there is one thing to be stressed in the treatment, it is early splinting, and the responsibility for this rests with the man in general practice. These cases are well within his province. The method of splinting and the position in which the hand is held will vary with different workers. The thinly-padded straight board splint, applied to the volar surface from the elbow to the base of the fingers, with the wrist joint held in 180 degrees extension, has been very satisfactory. Three one-inch strips of adhesive tape maintain the position; one applied at the proximal end of the board, one over the wrist joint, and one over the four metacarpals just distal to the web of the thumb. The board must never be wider than the part to be splinted. A plaster splint may also be used.

Board splinting may seem insufficient to the reader. It should be remembered, from a consideration of the anatomy herein set forth, that it is only necessary to put at rest the two main flexor tendons of the wrist; i.e., the flexors carpi radialis and ulnaris. They span both the wrist and midcarpal joints, and are inserted into the main unit of the hand circumscribed in Figures 1 and 2. Unless these tendons move, and one of them cannot move without the other, movement of any of the carpal bones in the proximal row is impossible. Splinting of the thumb to the side of the hand, in alternate cases, did not in any way alter the final result. Alternate cases have been splinted with the straight board splint on the dorsum of the wrist, with equally good results.

In recent cases with displaced fragments, the question of operative removal of the fragments arises. These cases, like the non-union cases, are problems for men of increased experience and, in any surgeon's hands, they will always demand considerable thought and a nice judgment. Some men will advocate immediate operation, and find their position well supported by the fact that attempts at closed reduction are apparently futile, and may actually further traumatize the joint surfaces. However, the amount of closed reduction which may be obtained in some cases, under full anesthesia, is surprising. In case operation is performed, and the fragments can be well fitted together, their removal is not absolutely indicated. If put up in a plaster cast for eight weeks, the patient may come off with a sound wrist.

Fracture of the scaphoid complicated by dislocation of the semilunar is fortunately the exceptional case. Under full anesthesia, many of these may be completely reduced, much to the surprise of the man who first attempts such an apparently hopeless task.

The case with non-union is an entirely different problem from the recent or fresh case. Here we find joint irritation with a potential synovitis and arthritis, superimposed upon an ununited fracture in a bone which normally enjoys motion in more than one plane. The prophylaxis in this type is the most important factor, and it is identical with accurate diagnosis and proper treatment in the fresh case. With few exceptions, the case of recent fracture recognized and properly splinted early in its course, need never fall into this non-union group. It is true, as any worker seeing many of these cases will admit, that it is very rare that one sees an old case, untreated, with a typical history, which will show a good result clinically, although *x*-ray examination shows a division of the bone in its middle, and the history and *x*-ray examination of the other wrist tend to rule out bipartite scaphoid. These rare cases reveal a most benevolent Luck, and should be anticipated with the same degree of uncertainty as are other modern miracles.

The non-union case is properly treated with a plaster cast extending from the base

of the fingers to the elbow, with the hand in moderate cock-up position. After a period of eight weeks, it may be removed to permit a check-up *x*-ray examination. If healing is not complete, another cast may be applied for a period of from four to six weeks. If, at the end of this period, *x*-ray examination shows no progress in healing, the patient may be permitted to go without any form of splint for a few weeks. If severe pain and weakness persist, the various operative procedures, such as drilling the fragments, with or without the insertion of bone pegs, and operative removal of fragments, may be considered.

After operative procedures, the prognosis must be guarded, especially after the removal of fragments. The wrist is weakened and pain may persist. In the event of such an unfortunate outcome, the patient has two alternatives; first, the wearing of a light steel brace holding the hand in a cock-up position, and second, submitting to an arthrodesing operation on the wrist joint, with the fixation of the joint in moderate cock-up position. This operation should secure a stable painless wrist. Loss of motion at the wrist joint is compensated, to some extent, by the presence of supination and pronation, flexion and extension at the elbow, and rotation and circumduction at the shoulder.

Fractures of the other carpal bones are also splinted on a straight board splint, or with plaster, and rarely cause trouble. If fracture of the semilunar bone is through the body of the bone, rather than a chip fracture, splinting for five weeks is in order. A patient with fracture of this bone should be warned, at the time of discharge, to return immediately for check-up *x*-ray examination if the wrist should again become painful. The etiology of Kienbock's disease is not clear, and some of these cases having a history of fracture or dislocation of the semilunar, later show irregular absorption and fragmentation of the bone. Fractures of the distal row bones should be splinted for three or four weeks. If the greater multangular is fractured, the thumb should be splinted to the side of the hand.

The occasional case in which *x*-ray examination shows an unidentified chip fracture, commonly found near the proximal row bones on the volar aspect, should be splinted from one to three weeks. A weekly examination directed especially toward noting whether or not there is pain on motion, and whether the grip is weak or painful, should determine the length of the splinting period. The small chip fragment is of no consequence in itself. It is invariably absorbed and completely disappears, as check-up *x*-ray examinations demonstrate. Its only significance is found in the realization that somewhere in the carpus, probably in the proximal row, there is a small bone area denuded of cartilage.

I am greatly indebted to Dr. E. R. Clark, Professor of Anatomy in the Medical Department of the University of Pennsylvania, for continued access to anatomical material, and to Mr. Varian, photographer in the same department, for the view shown in Figure 5. My thanks are due Dr. Lowry Allen, Roentgenologist to The Episcopal Hospital, for the *x*-ray films pictured in Figures 1, 2, 3, and 4. The diagrammatic insert in Figure 5 was drawn by Miss Edna Hill of the University of Pennsylvania Hospital.

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FRACTURES OF THE METACARPALS, METATARSALS, AND PHALANGES

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THERE seems to be a peculiar dearth of articles on the subject of hand and foot fractures in American, as well as English literature. Indeed, reports of injuries which are so common have been neglected, certainly not because of the lack of occurrence, but possibly because of lack of dignity which easily lends itself to major fractures. In this article the author will attempt to treat the subject in a rational manner by noting both cause and effect and by describing methods of treatment which can be used anywhere.

FRACTURES OF THE DISTAL PHALANX (FINGERS AND TOES)

Types:

1. Splitting Fractures. These are frequently longitudinal and without much displacement. They are commonly caused by blows on the end of the finger, as with a hammer, and are more frequent in amateur, rather than master carpenters. They are uncommon in the toes.

2. Chip Fractures at the Tip (Crushed Egg Shell Type). These fractures are also caused by blows on the distal phalanx but more often by severe "pinches" between two heavy objects. Dropping of heavy weights on the toes or "run over" accidents, in which the wheels of a heavy cart or hand truck pass over the tips of the toes, are common accidents. Frequently the soft parts are also injured. The nail may be completely torn off, or so loosened that its removal is necessary. The soft tissue at the end of the phalanx may be torn loose from the end of the bone, or the entire tip may be burst in such a manner as to resemble a crushed baked potato. Roentgenograms show the fragments more distinctly at the end of thirty days than at the time of accident! On the average, five months are required to demonstrate complete bony healing by *x*-ray. (Smith and Rider.)[15]

Treatment: These two types require simple treatment. Accompanying wounds must be treated promptly and thoroughly. They should be carefully cleansed, foreign matter removed by debridement, suitable antiseptics applied and then covered by sterile dressings. Suturing, of course, may be required. A small wooden tongue depressor splint applied to the finger may be used for protection against bumping. Drilling a hole in the nail to release accumulating blood beneath it will often give remarkable relief from throbbing pain. These fractures will all heal in due time even though multiple fragments are present.

3. Transverse Fractures. These may occur through any portion of the phalanx but most frequently in the middle. If the finger nail remains intact it acts as a natural splint. If the finger nail is lost some protection should be offered. Here again the tongue depressor splint is quite adequate treatment. It is padded lightly and strapped on with adhesive, care being taken not to cause constriction around the end of the finger. In the toes, simple bandaging or strapping together to the adjoining toe is quite sufficient. A hole may be cut in the end of the shoe or a house slipper can be worn for comfort.

Anatomical note:

The extensor and flexor tendons of the digits are inserted on the base of the distal phalanx (dorsal and palmar sides respectively) quite close to the last joint so that fractures beyond these insertions are not influenced by muscle pull. Sharpey's fibers which radiate out from

the bone to be inserted into the under surface of the skin form a dense mesh work, which further prevents displacement of fragments.

Fig. 1

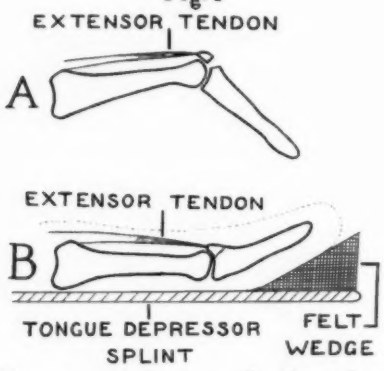

Fig. 1. A, diagram showing the pathology in "drop joint" or "baseball finger." Note the separation of the small fragment due to tension of the extensor tendon. B, note the reduction by hyper-extending the distal phalanx.

4. "Drop Joint" or "Baseball Finger" results from a pulling off of a piece of bone with the attached extensor tendon. It is a common summer-time injury. The disability caused by this injury extends far beyond the summer if untreated.

The clinical picture is that of a "dropped" distal phalanx with inability to bring about full, voluntary extension. The roentgenogram shows a small fragment of bone detached from the dorsal lip of the distal phalanx at the joint. This small fragment carries with it the attachment of the extensor tendon on the terminal phalanx of the finger. As a result the distal phalanx is flexed by the unopposed action of the flexor digitorum profundus, the extensor action having been lost. Consequently there is a rather marked space seen between the small detached fragment and the distal phalanx proper. (See Fig. 1.) Unless corrective treatment is instituted the "drop joint" deformity remains permanently.

Treatment: The fracture must be treated by "cocking up" the end of the finger, i.e., hyper-extension. This can be readily accomplished by applying a small padded tongue depressor splint with a felt wedge under the end of the finger to produce hyper-extension of the distal joint. (See Fig. 1.) Most of them so treated will heal without loss of function and without de-

Fig. 2. Roentgenogram showing the prolongation of the dorsal lip of bone at the base of the distal phalanx in an untreated case of "baseball finger." Patient is unable completely to extend the distal phalanx.

formity, but they must be kept immobilized constantly. Changing splints during the course of the treatment should be done with as much care as in changing a splint on a femur during the process of healing. It is the author's opinion that cases which he has observed with poor results have been those in which the patient, himself, removed the splints at various intervals and interrupted the continuity of the treatment.

Another excellent method of treatment is to lay a slightly curved, padded strip of aluminum on the back of the finger and strap it in place with adhesive. The extremity of the splint being bent backwards, somewhat, holds the distal joint in hyper-extension. At the same time the middle joint may be slightly flexed to relax the tension on the flexor tendons without losing any appreciable amount of hyper-extension.

If these fractures are not so treated, they will heal, it is true, but the gap between fragments fills with new bone and results ultimately in a prolongation of the dorsal lip of bone which forever prevents complete extension of that joint. (See Fig. 2.) *X*-ray films fail to show this new bone for several months. The average time required for complete healing is five months whether the fracture is treated correctly or not.

Clinically, of course, they appear healed in six to eight weeks as mentioned above.

A "drop joint" may also be caused by avulsion of the extensor tendon from its insertion on the distal phalanx *without* accompanying fracture. The treatment is the same, i.e., prolonged immobilization in hyperextension.

Fig. 3

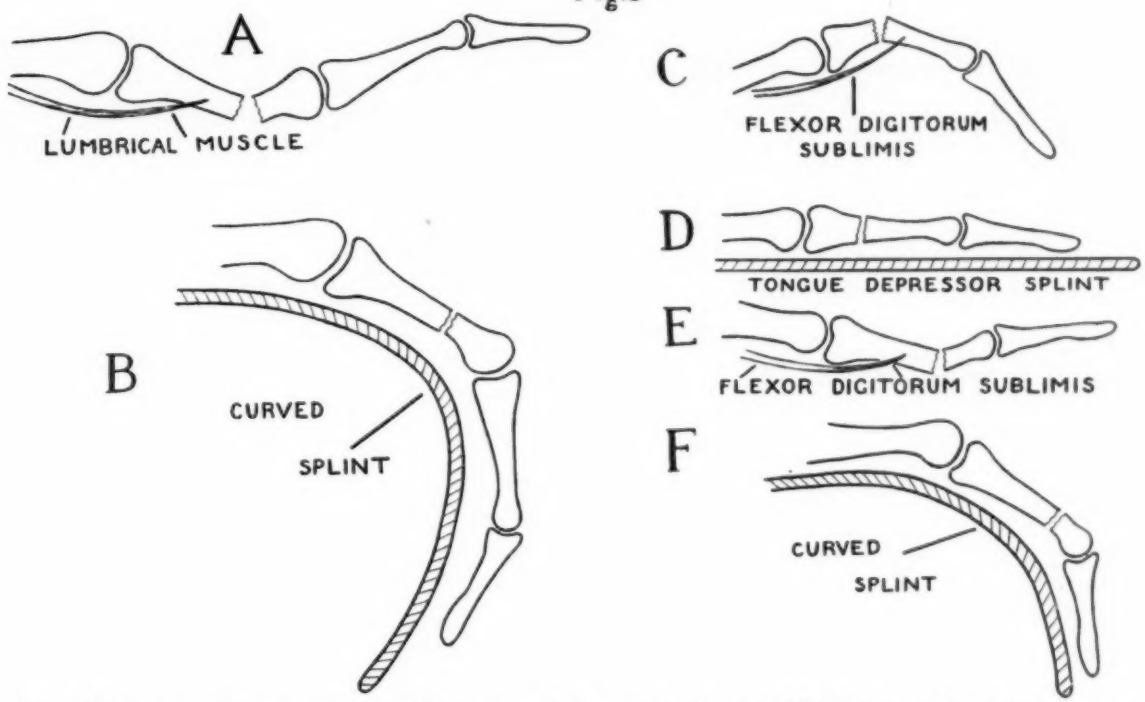

Fig. 3. Diagrammatic representation of fractures of the proximal and middle phalanges showing characteristic deformities. A, fracture of the proximal phalanx. The common deformity is one of angulation toward the palmar surface. This is due to the pull of the lumbrical muscle. B illustrates the reduction by flexion. The position is maintained by a curved splint made of light metal or plaster of paris. Flexion may be increased sharply if the palmar angulation is acute. C, fracture of the middle phalanx *proximal* to the insertion of the flexor digitorum sublimis. Note the angulation toward the dorsum due to bow-string action of the tendon. D, the same fracture reduced and held by a straight splint made of a wooden tongue depressor. E, fracture of the middle phalanx *distal* to the insertion of the flexor digitorum sublimis tendon. Note the angulation toward the palm. The flexor tendon in this case acts as a "guy rope" rather than a "bow-string." F, the same fracture reduced and position maintained by immobilization on a curved splint.

FRACTURES OF THE MIDDLE PHALANGES OF THE FINGERS

These are of more importance than those affecting the toes and so will be considered separately.

They are caused by a multitude of injuries, not one of which seems specific. Surprisingly, the incidence of fracture of the middle phalanx is much less than either of the other phalanges, its occurrence being only about 6 per cent of phalangeal fractures including both hands and feet.[15] Other authors have reported slightly higher percentages.[1,2]

Angulation at the site of fracture is common, though not the rule. Nevertheless an understanding of the simple anatomy involved is important.

Anatomical note:

The tendon of the flexor digitorum sublimis (the superficial flexor) is inserted on the under (palmar) side of the middle phalanx at about its middle. The angulation which this fracture assumes, if any, depends on whether the break occurs proximal or distal to the insertion of the flexor sublimis tendon.

(a) When the fracture is distal to the insertion of the superficial flexor, this tendon pulls the proximal fragment toward the palm causing a palmar angulation. Therefore, to obtain reduction the finger must be flexed to line up the distal with the proximal fragment.

(b) If the fracture is proximal to the insertion of the tendon, the pull of the flexor tendon will flex the distal fragment toward the palm, causing a dorsal angulation. In this case the finger must be dressed in extension possibly with traction to hold the alignment. McNealy and Lichtenstein have called attention to this principle in their articles.[1,2] J. A. Jahss also mentions the point.[3] (See Fig. 3.)

FRACTURES OF THE PROXIMAL PHALANX IN THE FINGERS

Fractures of the proximal phalanx may assume any form from oblique to transverse or nearly longitudinal. Frequently one sees considerable comminution. Usually angulation is directed toward the flexor surface (palmar side) due to the pull of the attached lumbrical muscle. It should be remembered that the lumbricals are the principal flexors of the proximal phalanges of the fingers.

Treatment is governed by these simple anatomical facts. Flexion of the finger is required to line up the distal with the proximal fragments. This may be accomplished in one of several ways.

1. A roller bandage is strapped in the palm of the hand. Traction is made on the broken finger, the fracture reduced, and the adhesive tape applied over the length of the finger to hold it in place.

2. A metal splint may be fashioned of aluminum or tin, bent to the desired shape, padded lightly, and, after reduction by mild traction, the finger strapped securely to the splint. A splint of this kind should be wider in the palm of the hand so that it will stay in place easily.

3. Jahss[3] recommends no splint at all, simply utilizing the principle of acute flexion by strapping the finger to the palm with adhesive tape. However, encircling bands of adhesive and acutely flexed joints, in the presence of fresh trauma, sometimes lead to trouble from swelling and must be watched carefully.

4. Continuous traction frequently offers better odds both as to reduction and absence from complications. It will be discussed later as it deserves special consideration.

FRACTURES OF THE SECOND TO FIFTH METACARPAL BONES

The causes of fractures of these bones are many, but aside from direct force and crushing injuries, the most common accident, if it can be called an accident, is a blow struck with the clenched fist. Here the impact is transmitted through the metacarpal and a break occurs anywhere along the shaft or head.

The angulation is fairly constant, there being an open angle toward the dorsum of the hand. If the break occurs near the distal head the same angulation persists, but there is frequently impaction of the fragments. They must be disimpacted to obtain reduction.

The lumbrical muscles, one to each finger, act like bow strings and are the principal flexors of the metacarpo-phalangeal or knuckle joints. Obviously to place a roller bandage or "sweet potato" splint in the palm of the hand is *not* the thing to do. Such palmar splints *increase* the deformity. Complete extension of the metacarpo-phalangeal joints, after manual reduction of the fragments, is highly important to hold the alignment. The terminal and middle joints of the finger may be flexed for comfort or to aid traction if it is used.

If reduction can be accomplished satisfactorily and if there is no tendency to lateral displacement, the hand may be immobilized with a moulded plaster splint extending well up the forearm and downward as far as the middle joints of the finger. A similar moulded splint should be used on the dorsum so that some compression can be made over the fracture site to prevent dorsal angulation. Thus the distal portions of the fingers are left free and motion in them should be encouraged while the cast is being worn.

Occasionally one sees fractures of metacarpals with no displacement and which require no splinting. A bandage should be

applied to act more as a warning signal than as an actual aid to treatment. Immobilization for three weeks is sufficient to produce clinical healing, but complete restoration of supporting strength of the bone is certainly not accomplished before twice that time. As in the fingers, roentgenograms fail to show complete bony healing before an average time of five months has elapsed. Continuous traction will be discussed later.

FRACTURES OF THE THUMB

Fractures of the distal phalanx are similar to, and are governed by the same rules as are terminal phalangeal fractures in the fingers or toes. The only difference of note is that they are more disabling, inasmuch as the thumb is the most important member of the hand.

Fractures of the proximal phalanx (there being two phalanges in the thumb) are more difficult to control. Transverse fractures frequently angulate toward the flexor side. In other types due to crushing injuries there may be impaction with little or no angulation. In either case reduction must be accomplished by traction and manipulation. In some cases, the position can be held by strapping the thumb across the palm with adhesive, using a small pad under the site of fracture to serve as a fulcrum—or a narrow plaster splint may be moulded to lay along the thumb and extend back onto the wrist. This is securely bandaged, keeping the thumb moderately flexed. Not infrequently, continuous traction will be found necessary.

FRACTURES OF THE THUMB METACARPAL

These are important particularly because of Bennet's fracture, which, if improperly treated, results in considerable disability. It is seen frequently along with other manifestation of fisticuffs and is sometimes made light of. I remember one amateur heavyweight who sustained this injury on a number of occasions, never letting one fracture heal until it was broken again. Needless to say, such trauma would incapacitate the average wage earner.

Bennet's fracture is characterized by the splitting off of the inner side of the proximal head of the thumb metacarpal at its articulation with the wrist bones, so that the whole thumb is allowed to slide backward and dorsalward. By pressing against the base while exerting traction on the thumb, the base can be felt to slip into place, only to slip out again when pressure at the base is released. If the thumb is widely abducted away from the palm before releasing traction the fracture is much more apt to stay in place. If this point can be established, then it is quite safe to treat such a fracture in a plaster splint which encases the forearm, wrist, palm and thumb to its tip. The thumb is held in wide abduction and the cast moulded to fit the base over the fracture site snugly and securely. This means little or no padding else the cast will become loose and the fragment will slip out again. Three weeks of immobilization are required in the cast. A snug bandage should then be worn for several more weeks.

Transverse fractures of the thumb metacarpal are not as frequent as might be expected. When they do occur they are frequently accompanied by severe soft tissue damage as this bone is well padded on three sides with muscle. If there is no displacement of the fragments, the fracture can be treated by using a simple moulded plaster splint as described before for fractures of the proximal phalanx of the thumb, but the majority of complete transverse fractures of this bone are best treated by continuous traction.

THE USE OF CONTINUOUS TRACTION FOR HAND FRACTURES

As has been mentioned, there are occasions when traction becomes necessary to reduce and hold both metacarpal and phalangeal fractures, with possibly the distal phalanx excepted. There are several, more or less standard, types of traction.

1. Skin traction is the simplest, and, for most cases, is satisfactory. One may use adhesive tape, running a one-half inch strip down one side and back on the other, leaving a one inch loop at the end of the finger for the attachment of a rubber band. It is further anchored by cross strips of adhesive and bandaged with a light finger bandage. (The principal cause of tape slipping off is the failure to keep a snug gauze bandage securely wrapped around the finger.)

Fig. 4. Illustrating the use of plaster of paris and wire extension splint for continuous traction. This is applicable to any of the metacarpals or phalanges. The plaster cuff is lightly padded so that it fits snugly. The wire extension is embedded in the plaster well above the wrist. A coat hanger is used for the wire.

2. Skin traction with glue, such as the "Ace Adherent" liquid, is highly satisfactory. The glue is painted on the skin, a narrow strip of bandage applied in the same manner as the adhesive tape, and bandaged in place by a light circular bandage. It withstands a heavy constant pull and does not irritate the skin.

3. Skeletal traction may be used by drilling a pointed wire or skin needle through the bone of the distal phalanx. The ordinary cambric needle is difficult to insert as it is too smooth at the point. The straight surgical skin needle with its triangular point is quite satisfactory but

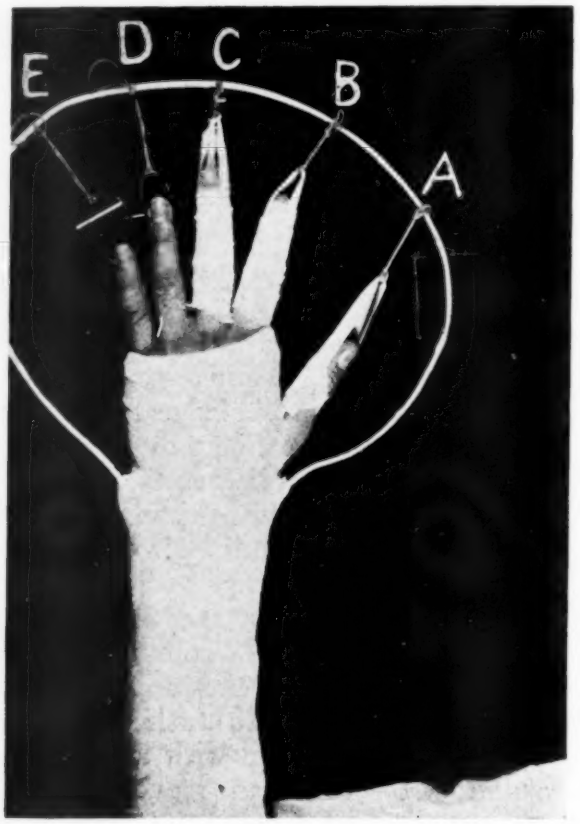

Fig. 5. A splint for several fingers is made as above. The wire is cut from a wire coat hanger and embedded in the plaster well above the wrist. This is the so-called banjo splint. Note the several methods of applying traction material. A shows the adhesive strips in place. B shows the adhesive covered with gauze bandage. Both are attached to the "Banjo" by rubber bands. C shows the strip of gauze bandage which is glued to the skin and held in place by a few turns of circular bandage (an excellent method). D, a pin has been put through the bone for skeletal traction. The sharp ends have been cut off and a wire stirrup fashioned of copper wire is attached. To this is fastened the rubber band for traction. E, a stainless steel wire has been inserted through the soft tissue near the tip of the finger and bent into a loop. Pressure on the sides of the finger is prevented by inserting a small spreader block inside the loop. Rubber bands provide continuous traction as above.

it must be drilled through with a rotatory movement. After passing it through the finger the ends are cut off and a stirrup made of soft wire is attached at either end to hold the rubber bands.

4. Traction through the soft tissue at the end of the finger, a method described by Böhler, has been found quite satisfactory. A piece of stainless steel wire sharpened at the point is pushed through the fleshy part of the end of the finger beneath the bone. It is then bent around in a loop and a small block of wood placed across this loop to prevent it from pulling together. This wire through the flesh will stand considerable traction without pulling out. In place of wire, a straight needle may be used and a small stirrup fashioned of soft copper wire, to which is then attached the rubber band for traction.

Having applied the desired traction material to the finger, or thumb, as the case may be, the next step is to supply the splint.

It is highly desirable to apply a plaster of Paris cuff on the forearm extending well up toward the elbow and ending below in the palm of the hand. The skin may be lightly padded with stockinet or cotton or both, avoiding excessive padding, as it permits the cast to slip and rotate. As soon as one or two bandages have been applied and the plaster has set, a wire extension is incorporated in the cast so that it will extend out beyond the end of the finger at least two inches. For this purpose, an ordinary wire coat hanger which can always be procured, serves admirably, or a piece of telegraph wire answers quite as well. (The coat hangers recently are coming in various pastel shades, which lend something to appearance!) A pair of mechanic's pliers is the only tool necessary. The wire is bent into a long narrow "U" shape, about 1 inch between sides. The proximal ends are bent back on themselves to give more purchase in the plaster. The portion to be left outside the plaster is well padded and bandaged. When the whole cast is set and the incorporated wire held firmly in place, the rubber bands can be attached from the finger to the end of this splint. (Fig. 4.)

A great advantage of this type of splint is that it may be bent at any point desired and still maintain traction in the longitudinal direction. It also permits easy access for dressing and inspection of wounds. It may be used for any fracture of the fingers or metacarpals where continuous traction is needed.

If two fingers are involved, the wire may be widened enough to accomodate both fingers, or, if they are not adjoining, two wire loops can be put on.

When there are multiple fractures of fingers, or if there are several metacarpals fractured, or if there are various combinations of metacarpals and fingers fractured, it is better to make a large loop around the whole hand, i.e., the classical banjo splint. This can be made the same way, the coat hanger or telegraph wire making the banjo which is incorporated in the plaster above the wrist as described before. (Fig. 5.)

In a complicated case, when a combination of extension and flexion is desired, a second banjo can be incorporated so that one can be used to give flexed traction and the other to give counter extension. A small belt of webbing or firm bandage can be placed under a given phalanx for this purpose so that counter extension can be made while flexed traction beyond that point is being maintained.

Various ready-made splints may be had, but are seldom necessary. Their cost is greater than plaster of Paris, and most of them do not fit well unless made for the individual patient.

FRACTURES OF THE PHALANGES OF THE TOES

These are still common injuries, although their incidence in up to date industrial plants has been greatly reduced by the introduction of safety shoes. Thus we have a least one type of fracture which can be given prophylaxis. Safety shoes differ none in appearance from ordinary shoes,

but in the toe portion is a steel cap covered with leather which will withstand terrific weight without crushing. Many a toe has been saved by such a simple device. A more general use of such shoes would be of great service in industry. They cost no more than ordinary shoes.

The distal phalanges suffer the same types of injuries as do the fingers and the treatment is the same. Walking is usually permitted in a day or two, unless complicated by skin laceration or other injuries. Strapping the toes together sometimes affords relief and wearing a shoe with the toe cut out avoids pressure-pain when walking. By the end of three or four weeks there usually remains no indication of injury. *X*-ray pictures nevertheless still show the un-united fragments, as in fingers, well up to the fifth month.

FRACTURES OF THE MIDDLE PHALANGES

The middle phalanges of the toes (exclusive of the great toe, which has none) are nearly cuboid in shape and hence are not often fractured. If they are fractured they assume no classical displacements (in contrast to the fingers) and, therefore, require very little special consideration. If they are crushed, traction is probably the best treatment, for it not only provides straightening, lengthening force, but also permits dressing.

SMALL CHIP FRACTURES

These are occasionally seen near the joint surfaces of the middle phalanx and may arise from either the distal, middle, or proximal phalanx. They are seen in "stubbed toes" especially during the barefoot season. Such fractures are painful, not so much from the standpoint of the fracture, as from the accompanying joint injury. Usually three weeks' time will suffice for a cure, although occasionally there is soreness in the joint for a longer period. However, most of the pain occurs at the time of the accident, to which the author can attest from personal experience.

FRACTURES OF THE PROXIMAL PHALANX

These assume an aspect of more importance. Angulation, (as in the hand) if present is frequently toward the flexor surface. And, (as in the hand) traction with some flexion may be indicated. However, in most cases simple dressing, strapping to the adjacent toes, or small wooden splints will be sufficient. Many of these cases can bear weight with a "cut out" shoe and attend to their daily routine. However, those involving the great toe had best not bear weight. Bohler[4] recommends a walking cast for proximal phalangeal fractures of the toe, "strange as it may seem," as he states, and obtains very good results. His contention is that patients are better able to walk with the walking cast (a non-padded plaster boot with "U" shaped iron stirrup attached) than they are by trying to walk on their heels. (Fig. 6.) Davis[5] has described an ingenious wooden splint to fit either right or left foot, suitable for either toe or metatarsal fractures. He recommends its routine use in these fractures if some traction is to be exerted. It consists of an arched board with six tongue-like prolongations at the anterior end for fastening to the toes. By using adhesive strapping he exerts traction on one or all toes as desired.

FRACTURES OF THE METATARSALS

In his text "Fractures and Dislocations" Kellogg Speed[6] makes the following statement:

> Metatarsal fractures, though relatively common, are often overlooked. They are most often found among laboring men and are caused by direct violence, such as the dropping of burdens or heavy objects on the feet. . . . The metatarsal bones are so closely packed together and surrounded by muscles and the heavy planter tissues that displacement after fracture is not great, unless several are broken at the same time.

It is important that injured feet be *x*-rayed. If there is not much displacement

or angulation, a moulded plaster sole can be fashioned to extend from the heel to the toes and bandaged in place. This affords the simplest protection, and must be used in conjunction with crutches. Its only merit is in preserving the arch.

A better method is to apply a boot cast extending well up the calf of the leg and well moulded under the arch so that there will be no "give" if weight is borne. Many of these patients can walk using a walking cast with attached metal stirrup. (Fig. 6.)

If there is displacement of fragments they should be re-aligned by manipulation, either under general or local anesthesia, and a plaster boot snugly applied. If comminution is present, or if it is difficult to hold the reduction, continuous traction should be employed. Five to six weeks is required for a good clinical union.

Fracture of the tuberosity on the proximal end of the fifth metatarsal occurs occasionally, as a result of muscle pull, or from a direct blow. Attached to this tuberocity is the tendon of the peroneus brevis muscle, so that separation of fragments is to be expected. Such is the case to a certain extent, although the ligaments and muscle attachments of the abductor digiti quinti tend to lessen the separation. These fractures are quite painful and if weight bearing is allowed at all, a hole should be cut in the shoe and the area over the fracture firmly strapped with cross straps of adhesive. Some cases are better placed in a plaster boot for a few weeks and given complete rest. In neglected cases with separation of fragments and pain, the loose fragment may be removed.

CONTINUOUS TRACTION FOR FOOT FRACTURES

A plaster boot extending from just below the knee to the toes is required. A wire loop like the banjo for the hand, only not so wide, is attached to the foot portion and from it traction made to the toe or toes.

As described for the hand, adhesive tape, "Ace adherent" liquid, glue or skeletal traction may be used. Toes vary considerably in size and shape and not infrequently one is unable satisfactorily to bandage a toe in a circular manner. Such cases can be treated by the insertion of wire or skin needles through the tips of the toes and attaching them to the banjo by rubber bands.

Fig. 6. The "walking cast." The cast is non-padded except at the upper end where there is an encircling collar of felt. The U-shaped metal stirrup is embedded in the cast and extends beneath the sole two-finger breadths. The plaster must be applied perfectly smoothly on the skin to avoid any possible irritation from wrinkles. Weight bearing is permitted the following day.

Phalangeal and metatarsal fractures with over riding, or when compounded, are best treated this way.

Traction need be left on only until the bone is sufficiently knit to remain in place, two to four weeks being required. Traction can then be discontinued, but in the case of metatarsal fractures some protection must still be provided for three to four weeks more. This can be done with a

walking cast, as previously described (Fig. 6) which enables the patient to become ambulatory without the need of crutches: or, simple bandaging, with a felt pad beneath the arch for additional support, may suffice. Unaided weight bearing is resumed gradually.

MARCH FOOT, MARCHING FRACTURE, PIED FORCÉ

The first reference in American literature to this condition came in the form of an editorial,[7] which was really an abstract of the observation of a Prussian military surgeon, reported at the international congress in Spain, 1899. *X*-ray photographs were shown to substantiate the evidence. Since then, many references have been made in European literature but only a few in English or American journals. The latter are namely by Jansen,[8] Goldman,[9] Morton,[10] Strauss,[11] Monteith,[12] H. Blauvelt,[13] and Edward.[14]

The description given by Jansen[8] in his paper read before the British Orthopedic Association is classical. Extracts are quoted as follow:

> March foot is an edematous swelling of the metatarsal region of the foot which presents itself in persons who are made to walk beyond their strength. The pain, if present, is not severe at first. Swelling appears on the dorsum of the foot, next on the plantar surface, the latter in a less degree. . . . In the beginning the swelling soon disappears with rest, sometimes in a single night, and reappears with new fatigue. . . . The roentgenogram shows no changes in the bones at the onset. In the course of a few weeks however, "even" thickenings on the metatarsal bones develop along the diaphyseal portion. . . . They are never observed in those parts of the metatarsal from which no interosseous fibres (muscles) arise (first metatarsal and lateral side of the fifth.) During the development of the phenomena, a metatarsal fracture may occur without a preceding trauma or even a sensation of pain so that the fracture is often a surprise both to the doctor and the patient. The first metatarsal is never fractured, the fifth only in .6 per cent of the cases. . . . They are more frequent in the second (54.5 per cent), less in the third (36.8 per cent), and least in the fourth (2.5 per cent)
>
> Summarizing we may say that March Foot is due to over fatigue in a weak foot . . . causing eventual fracture.

Goldman's[9] case occurred in a pedlar who daily carried a pack weighing about 80 pounds. He was 29 years old and sustained a fracture of the second metatarsal typical of "march foot."

Strauss'[11] case was in a woman from whom the affected metatarsal was removed following a roentgenographic diagnosis of sarcoma. Upon removal it was found that there was a fracture of the shaft of the metatarsal surrounded by excessive callus which had not yet ossified. The fracture could not be demonstrated on the *x*-ray film.

European literature contains records of many cases and undoubtedly there are many which exist, unrecognized, here. As has been pointed out, the presence of frank fracture demonstrable by *x*-ray is the exception rather than the rule. I have seen three such cases which might have progressed to that point had not treatment been instituted.

Treatment consists in rest and immobilization. A plaster boot is excellent treatment and guards against weight bearing. Usually a few weeks in the cast is sufficient. Then if the shoes are properly fitted, the arches given some attention, and a judicious program of foot exercises prescribed, one can expect a cure.

CONCLUSION

It would be impossible to cover every phase of this subject—the matter of compound fractures, tendon injury, joint disturbances and plastic procedures, being lengthy chapters in themselves.

However, it is hoped that this brief discussion will bring out a few facts which have heretofore been given too little attention, namely:

1. That there are other ways of treating fractured fingers than with tongue depressor splints.

2. That traction is an important form of treatment for fractures in the hand and foot.

3. That the healing time of these small bone fractures is considerably longer, as shown by *x*-ray studies, than is commonly supposed and may account for the prolonged pain in certain cases where function is resumed too early.

4. That "march foot" may be much more common than has been supposed.

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FRACTURES OF THE STERNUM AND THYROID CARTILAGE

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FRACTURES of the sternum occur fairly often in this day of increasingly common automobile accidents, although they are generally overlooked and usually untreated. Failure of recognition is due to the fact that other more serious injuries such as fractures of the vertebrae or injuries to the head divert attention from the sternum at the time of the accident. Also adequate *x*-rays of this bone are difficult to procure. On the other hand, there is little reason to make *x*-ray examinations of the sternum on every patient with pain in the chest after an accident.

Most previous statistical reports of series of fractures in which a very small per cent involved the sternum have little value. They were made before the modern *x*-ray was developed, and consequently many of the less severe cases were overlooked. Gurlt studied the records of all fractures treated in the London Hospital before 1864 and found only twenty-two cases of fracture of the sternum. Again in the first fifty-four years of the experience of the Massachusetts General Hospital there were only four reported cases. It is readily apparent that such studies which were reported before the *x*-ray was in common use have little more than historical interest.

In 1933, I collected and reported eight cases of fracture of the sternum which represented the total number that had been seen at the Mayo Clinic. Yet even in that series, four of the patients had come to my notice within an eight month period in one year (1932). Therefore, I think it is safe to say that many fractures of the sternum are unnoticed when graver injuries are present and consequently do not receive specific treatment.

Fractures of the sternum are most often produced by direct blows immediately over the front of the chest. Thus when a person is thrown against the steering wheel of an automobile in collisions, the sternum receives most of the force of the blow. (Fig. 1.) In addition, in "jack knife" injuries in which the torso is acutely flexed, the sternum may be crushed. Cases have been reported, furthermore, in which prolonged labor, with the accompanying strong muscular contractions, fractured the sternum by indirect force. The greater number, however, are fractured by direct blows.

Despite the fact that the sternum is in the anterior chest wall, it is moderately well protected against direct injuries. The ligamentous sheath which completely surrounds it softens the effect of blows and protects the fragments from gross displacement while the anterior chest muscles cover more than half of the exposed surface of the bone. An even greater protection is afforded by the attachments of the costal cartilages on each side which contain joint capsules that are mobile and elastic and therefore resistent to fracture. The only relatively rigid attachment of the sternum is at the upper border of the manubrium where the clavicles and first pair of ribs join it. This also is the thinnest portion of the bone. Therefore, it is in this region or near the junction of the manubrium and body that fractures most often take place. (Fig. 2.)

Since the sternum does not become solidly ossified until the age of twenty years, fractures in children are quite rare. Hence if a child receives a direct injury in this region, it is more likely to produce a dislocation at the articulation between the manubrium and body. In adults, the

fractures of the sternum occur immediately above or below this articulation and the upper fragment is usually displaced behind the lower fragment.

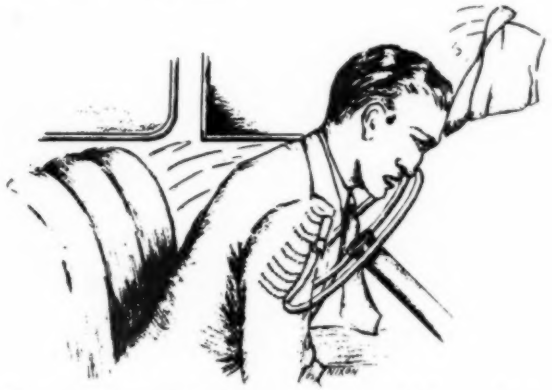

Fig. 1. The usual type of injury which produces fractures of the sternum. Most of these fractures occur in automobile accidents.

Other more serious injuries frequently accompany fractures of the sternum, such as fractures of the dorsal vertebrae, ribs, or costal cartilages. Since the sternum itself is well protected by ligaments and muscles, the fragments are seldom grossly displaced and they very rarely damage surrounding structures. There have been cases reported, though, of lacerations of the trachea from fragments of the sternum, or rupture of the internal mammary arteries with hemothorax and traumatic pneumonia.

A patient with fracture of the sternum develops sharply localized pain and voluntary immobilization of the chest. He breathes mainly with his abdomen and holds the head in one position to prevent torsion of the sternum through the sternomastoid muscles. Sometimes there is a depression of the skin over the fracture, crepitation, or other gross evidence of injury. Lateral *x*-rays of the sternum will show the bone detail clearly and demonstrate any fracture present. (It is obvious that antero-posterior *x*-rays are worthless since the spinal column and mediastinum blot out the sternum.) Even better detail of the bone may be brought out by oblique *x*-rays taken when the respiration is suspended in inspiration so that there is a clear space between the pericardium and sternum.

The treatment of fractures of the sternum is mainly conservative so that operative correction is rarely required. Patients with such a fracture should be placed on a stiff bed with a small sand bag between the shoulders to prevent flexion of the chest. Hyperextension of the spine is further produced by placing a pillow beneath the loins and a figure-of-eight bandage across the shoulders posteriorly. In cases with serious over-riding of the fragments, a hyperextension frame, such as is used in fracture of the spine, should be used to reduce the deformity and to relieve pain. As the pain and acute tenderness subside, the patient can be allowed up and about though he should wear a T-splint or spinal brace for several weeks. The fracture heals solidly in about six weeks and symptoms are usually absent after that time. Nevertheless, the patient should avoid heavy lifting and strenuous exercise for at least three months from the time of the accident.

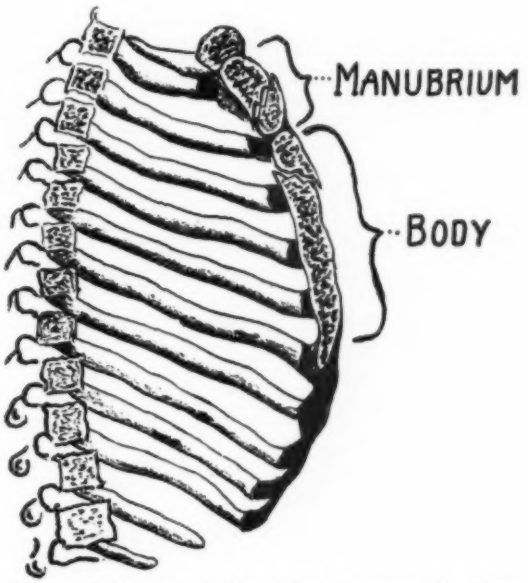

Fig. 2. Diagram of the thoracic cage showing the common locations for fracture of the sternum.

A bothersome complication of fractures of the sternum and one which frequently leads to medico-legal conflict is the occurrence of persistent pain about the costal

cartilages many months after the accident. This probably results from injury to the costochondral junctions, to the cartilages themselves, or to the articulations between the costal cartilages and the sternum. In any event the repair of this cartilage tissue is slow and there may be false motion and pain for months after the bone itself has healed. Moreover, the crack in the cartilage can seldom be demonstrated by the *x*-ray, and diagnosis must depend upon the symptoms and physical findings. To shorten the disability in such cases it is well to keep the chest strapped as long as there is any pain about the sternum.

FIG. 3. The type of blow which produces fractures of the thyroid cartilage. It is struck from the front and forced violently against the vertebral bodies.

FRACTURES OF THE THYROID CARTILAGE

Fractures of the thyroid cartilage are serious injuries although fortunately they are quite rare. They are infrequent because the larynx is well protected by the overhanging chin and the soft tissues of the neck that are sufficiently mobile and resilient to resist blows. It is well that this is so, since such fractures produce death in 70 to 80 per cent of cases.

The cartilages of the larynx are subject to injury from two types of forces: (1) blows from the front as in falls, fights, or automobile accidents, which crush the larynx against the vertebral bodies (Fig. 3); (2) crushing or side-to-side compression injuries produced by hanging and criminal attacks (choking or garroting.) In all the various injuries which involve the larynx, the thyroid cartilage is fractured far more often than any of the others because of its relative size and prominence as compared with the other component cartilages in the larynx. Adults, and for the most part, males make up the group in which fractures of the larynx occur since the cartilages in men begin to ossify at 25 years of age and are completely ossified at 65 whereas the cartilages in women are less likely to ossify at all. However, there have been cases of women and children receiving such injuries. The most characteristic type of patient to receive a fracture of the thyroid cartilage is the slender long-necked young man with a prominent Adam's apple and poor general muscular development.

When the thyroid cartilage is fractured there is much immediate local swelling and tenderness as well as interference with swallowing and phonation. Frequently this is followed by bloody sputum and some ecchymosis of the neck. The patient holds his neck rigid because motions of the head produce pain. Unlike other fractures, crepitation is seldom present because of the marked swelling about the fracture and the flexibility of cartilage tissue. *X*-rays likewise are in most cases negative since cartilage injuries are difficult to demonstrate by roentgenograms. If the perichondrium of the larynx is torn or if there are large lacerations of the laryngeal muscles, emphysema may develop rapidly and spread into the neck and thorax. The gravest of all symptoms, edema of the glottis, sometimes takes place so rapidly that death may ensue before medical aid can be summoned.

A patient who has received a fracture of the thyroid cartilage should be put to bed (preferably in the hospital) where he can be watched very closely for any evidences of embarrassed respiration. He should, moreover, receive ample morphine to relieve pain and apprehension while ice packs are applied to the neck to reduce the edema. Nasal feedings can be used if swallowing is too difficult. In the first days after the accident it is well to forbid talking in order to put the voice at complete rest. Furthermore it is essential that a tracheotomy set be available constantly for several days; for if breathing becomes labored, such an operation will need to be performed immediately. Tracheotomy when necessary must be performed as low on the trachea as possible to prevent damage to the cricoid cartilages. These will be so surrounded by edematous tissues that identification of structures may be difficult. Steam inhalations afterward will do much to prevent pneumonia and if there is excessive salivation it can be controlled with atropin. As soon as the patient is comfortable, the vocal cords should be examined to see if there has been any contusion which will require specific treatment. It is well to remember too that the arytenoid cartilages are easily dislocated by violence and that this in turn may cause permanent damage to the voice box if untreated.

There are numerous complications which may follow injuries of the thyroid cartilage and these must be borne in mind during the entire course of treatment. Any interference with breathing which is not promptly relieved may readily produce suffocation and death or lead to bronchopneumonia. Contusions of the voice box which are not recognized or properly treated may result in stenosis of the larynx. Also if the muscles of the larynx are lacerated extensively, aphonia may persist despite the best treatment. In severe crushing injuries to the larynx or after tracheotomy, any infection which may develop can spread directly into the posterior mediastinum since anatomically, the trachea may be said to lie in the visceral space of the neck. Consequently infection must be carefully guarded against when treating any wounds of the neck.

If there has been no gross displacement and if the vocal cords have not been damaged, recovery from fractures of the thyroid cartilage is usually complete. However, for two weeks after the accident the patient should be under close observation and subsequently he should rest the voice as much as possible for at least a month before he can be finally dismissed.

One is often unable to distinguish injuries to the thyroid cartilage from those which involve other cartilages in the larynx. This is unimportant because the symptoms are much the same, although in fractures which involve the cricoid and arytenoid as well as the thyroid cartilage, the mortality is nearly 100 per cent. The diagnosis and treatment of all injuries of the larynx follow the same general plan so that the recommendations mentioned will anticipate, for the most part, any serious complications in patients with fractures of the cartilages of the larynx.

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SKELETAL TRACTION IN TREATMENT OF FRACTURES

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TRACTION is the most valuable treatment offered fractures of long bones, particularly in their diaphyseal or shaft portions. The ancients realized the importance of traction as a means of restoring limb length and axis, employing such forces as those obtained by a windlass or manual pull. Our modern methods are based on the same mechanical principle and in recent years have leaned strongly toward the type of suspension traction, combined and first well adapted in the United States by Hodgen. His leg splints took advantage of the weight of the limb as an automatic agent for its own traction.

The advance of aseptic surgery then permitted an even greater opportunity for direct traction by means of skeletal pull—that is, traction applied to a bone through an opening in the covering soft parts, be it skull or the phalanx of a finger, for direct pull upon the bone to correct angulation overriding or axis where wounds or other soft part damage interfered with simple forms of external splintage.

The first best example of the application of this principle of exact and powerful pull on bone itself was proposed by Ransohoff of Cincinnati and was based on the lifting hold obtained by ice tongs. One recalls, before the days of the universal electric refrigeration, the ice man's tongs dangling on the hook at the back of the ice wagon and their sure and powerful hold on the 100 pound chunk of ice as the ice man sank them into the solid cake and casually swung it up on his shoulder. The harder the pull or the greater the weight, the deeper became the insertion of the sharp points with resulting tenacious grip. This was adapted to long bones, using miniature tongs which gripped the surface of a given bone or bones into the periosteum through small and innocuous wounds in the soft parts. To these tongs could be applied balanced and continuous traction with or without suspension which took advantage of the weight of the limb or torso as an agent of counter traction.

Refinements of skeletal traction were soon introduced by Steinmann, who used a pointed steel rod, like a roast beef skewer, which was aseptically driven through the bone at the elected point. Later by the use of a finer caliber steel rod, Kirschner employed wires which can be easily and rapidly drilled through soft parts and bone to give, when gripped in a proper locking device, steady pull on a part with a minimum sized wound and a greatly reduced chance of infection or possibility of bone splitting or injury. The fine wires of the Kirschner traction can sustain heavy pulls on bones, but will cause a certain amount of pressure (aseptic) necrosis against their pulling surface which might result in splitting a bone, or if left in position with too much traction over a long period of time, penetration into a near-by joint or epiphyseal area.

All these forms of skeletal traction may be amplified by secondary pins or wires which permit counter traction or pull, enabling the surgeon to apply an enormous distracting power in opposite directions on a bone near the site of fracture; an easy and complete reduction of fracture with correction of length and axial misalignment may follow. From this has developed such portable machines as the traction apparatus devised by Roger Anderson, and others, which in expert hands may straighten out bones and assure their position by holding the pins which correct displacements embedded in plaster of paris encasements.

The average medical man may not be armed with these complicated and expen-

sive machines but he may accomplish the same results by use of simpler measures and perseverance. He may employ simple skeletal traction at one end of a bone and depend on body or limb weight to give the counter pull without using multiple punctures of limb and bone by the foreign body, no matter how small of caliber it may be.

There are certain elementary indications for the use of skeletal traction after fracture of long bones and no matter how, or by whom, or with what method the job is done, these rules must be complied with or disaster may follow. Skeletal traction is a most valuable and powerful remedy—at least ten times as efficient as skin traction—and it must not be employed without due consideration for fear that it may endanger the patient, the surgeon's reputation, or as a measure fall into unwarranted disrepute. It may often be combined with burial of pins or wires in plaster of Paris to permit ambulation when used on either upper or lower limb. My purpose is to call attention to these elementary indications and rules too often ignored by the casual operator.

Indications for use of skeletal traction are:

I. a. Open fracture, recent.
   b. Open fracture, infected.
II. Closed fracture.
   a. Neglected with resulting overriding, shortening or angulation. May have been in a plaster of Paris dressing.
   b. Skin lesions at or near fracture site which forbid skin traction. These are often blebs or abrasions.
   c. Skin lesions caused by misapplied or removed skin traction.
   d. Large hematoma within the limb.
   e. Failure of manipulation of skin traction to obtain reduction of fragments within a reasonable time.
   f. Double or multiple fracture of long bone.
   g. As an excellent substitute for major open operation where the surrounding conditions are unfavorable for surgical procedure.

These points require but little amplification. It is understood that the handling, observation and dressing of an open fracture is much safer and simpler when the bone is held rigidly in traction and does not move or angulate during any procedure necessitated by the wound, whether that is a simple change of dressing, irrigation or any other method selected by the surgeon. If all open fractures of the lower limb were treated by skeletal traction from the very first, after proper debridement and surgical care of the wound, there would probably be far less chance for infection with resulting prolonged care, local osteitis or even loss of limb.

When an open fracture is already infected and measures such as drainage or other surgical attack must be instituted, there is increased demand for security in the limb's position and axial alignment during the course of treatment and repair.

The closed fractures with overriding and shortening or angulation, may be brought into full length and straight line even after they have been given inadequate pull or attempted reduction followed by splintage of some sort. The great power of skeletal traction may effect reduction, provdied that union has not already started and new bone has not blocked the possibility of moving the fragments out into normal position. Time enters here as a factor which varies with the patient's age and the bone involved, young bones throwing out callus and uniting more quickly than old ones.

Skin lesions, such as blebs, burns from skidding on foreign surfaces, abrasions, infected or potentially infected, with inground dirt which requires scraping removal, may at the very start of treatment of a fracture forbid the use of skin traction applied by adhesive tape or any of the various glues. Frequently when a skin traction has been misapplied, without cleansing or shaving the skin surface, the

removal of this tape either by slipping while in traction, or by the patient's misguided efforts or the surgeon's thoughtlessness, may leave abraded bleeding surface on which skin traction cannot again be applied. To ensure traction throughout the period required for bony union, skeletal traction is demanded at once.

Large hematoma within a limb, making it bulky and heavy, with increased tendency for the enclosed muscles to enhance shortening or over-riding, requires the kindly and powerful pull of skeletal traction. Without this aid, secondary deformities are bound to occur. Also, when manipulation and skin traction, if checked in due time by length or other measurements and controlled by *x*-ray examinations, fail to give proper reduction, one must be morally bound to use skeletal traction if the process of union has not gone on to a point which would nullify the attempt.

For double or multiple fracture in a long bone, especially the femur or leg bones, skeletal traction will frequently bring widely angulated and displaced fragments into line and length, guided by the ensheathing or vaginal-like action of the surrounding muscles made taut by this powerful force. By using skeletal traction within the scope of its indications and under the rules to follow, many apparently hopelessly displaced fractures may be brought into satisfactory position and the danger of major operative procedure can be avoided, much to the patient's benefit.

RULES FOR USE OF SKELETAL TRACTION

The following rules for the use of skeletal traction have been followed consistently by the writer. They are time tested and worth considerate attention by all using this method of fracture treatment:

1. Careful asepsis; not only of the in or through driven metal agent used to obtain the skeletal traction, but also of the patient's skin and soft parts regardless of the area involved. This is particularly true near the foot, which is always soiled, or near the anus, where the possibility of infection on any skin is great.

2. A simple and rapid insertion of pin or wire is required. That means a minimal sized wound, a complete anatomical knowledge of the part of the bone to be penetrated and a rapid penetration devoid of puttering or repeated useless attempts with greater possibility of infection or injury of important structures such as joints, blood vessels and nerves.

3. A plain dressing, or in some instances no dressing at all, is required if the insertion is through a part such as the heel where suspension traction will permit the wound to remain partly open and in full view without immediate contact with any neighboring surface. Collodion, vaseline dressings or wadded gauze are not required unless the part is to be imbedded immediately in plaster of paris, in which instance a light layer of plain sterile gauze may be placed protectingly over the site of the wound of insertion and exit of the metal agent, whether pin or wire.

4. A proper sized agent, pin, tongs or wire, must be employed, depending upon the bone and the age of patient on whom the apparatus is fastened. Too large a pin may split the heavy expanded lower end of a femur or the upper end of the tibia. Very delicate tongs may be used for skeletal traction on the phalanx of a finger. Suitable pins and wires, which will not break under the tension required for the given case, must be selected intelligently and in advance.

5. Avoid hematoma about fracture.

6. Avoid joints.

7. Avoid epiphyseal planes.

5, 6, and 7 are the important "don'ts." One should religiously avoid the hematoma about the fracture. Nothing offers a better medium for the growth of even a minimum number of bacteria in the limb than the spreading hematoma originating from the fracture. The surgeon must recall that this hematoma may extend from one end of the limb to the other and even beyond some

of the larger joints in severe injuries. To infect this blood will lead to the immediate infection not only of the soft parts invaded by it, but, by direct continuity, of the fractured bone. Likewise one would never knowingly pass a metallic agent through a joint surface for the purpose of traction and similarly one would never penetrate the delicate growing area of the epiphysis in an adolescent. Growth might be interrupted in whole or part in this area with resulting deformity and possible grounds for legal redress on the part of the patient.

8. Don't put off use of skeletal traction too long; that is, do not expect this wonderful power to work a miracle if the bone has already started to heal or the soft parts and muscles are so contracted or influenced by infection that elasticity and the hope of regaining length is lost.

9. Do not over-pull the fractured surfaces by using too much weight and counter weight. Nature abhors a vacuum between bone ends just as much as she does in other locations. Bone will not bridge between over-distracted fragments and often, when this over-pull is discovered, and weights are lessened to slack off the force, the bone contrarily will not retract back into a pleasing apposition. Soft parts or periosteum may have been permitted to fall in between bone ends. Non-union may result from this situation. Watch and control the amount of pull and position of fragments by *x*-ray.

10. Try to feel bony crepitus at the fracture site, after the skeletal traction has been inserted and the pull applied, by whatever means is employed. It is very comforting to know that raw bony surface is rubbing against itself because it eliminates much chance of interposed periosteum or soft tissues and may be insurance against delayed or non-unions.

11. Skeletal traction, watched and efficient, should really be left on the limb until enough bony union has developed to hold length and axis and not permit shortening when the pull is relaxed and a different or possibly an ambulatory type of splint is applied. This is one of the greatest faults in the use of all types of traction in the hands of the average man treating broken bones.

12. Control position and degree of union between fragments by *x*-ray. This may be troublesome or even expensive, but it pays large dividends in successful treatment and a more or less exact knowledge of position of the parts involved in at least two planes as well as the degree and extent of ossification before traction is released and any substitute or convalescent splint is applied to the still young and weak bony healing.

Consideration of these rules, with a compliance to the general indications in the selection of patients to be treated by skeletal traction, cannot fail to raise the percentage of happy and safe outcome in anyone's hands. Perhaps few types of human ills require the time and energy consuming effort demanded by fractures, and when skeletal traction is used the surgeon's watchfulness must be increased.

FRACTURES OF THE SPINE

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FRACTURES OF THE VERTEBRAE

WITH the ever increasing activity of industry and transportation, the hazard of injury becomes greater and in the field of spinal injury this is strikingly true.

Fractures of the spine are no longer a rarity in the average physician's practice, so that it becomes increasingly necessary that he qualify himself in the diagnosis of this injury; and in every community there should develop at least one who is prepared to handle the details of treatment.

Previous to the present era, a broken back or a broken neck were looked upon as a catastrophe, and it was taken for granted that all resulted in complete invalidism or in death. It is now known that much more than half of all fractured spines have little or no spinal cord or nerve root damage resulting in paralysis, and that such cases, treated properly and early, can be restored to a comfortable and useful life, and in many instances returned to their previous occupations, no matter how strenuous those occupations may have been. Moreover, in certain groups of cases, where paralysis from pressure develops following injury, this paralysis can be relieved by what now seem very simple procedures.

It has only been within the last ten years that our knowledge of the incidence and treatment of spinal fractures has taken such a forward step, and this is due to the increased facility of diagnosis through the improvement of *x*-ray technique.

The spine should be considered as a whole, as a single functioning part of the body. Its purpose is to carry the weight of its superincumbent structures, to provide flexibility to the body, to protect the spinal cord, and to provide means of attachment for the muscles. It is firmly bound together by a dense and intricate ligamentous system which allows for flexibility, and at the same time controls stability. The individual units are made up of an anterior portion, the vertebral bodies, which form a sponge-like bone that is to a large extent the weight-bearing portion; whereas, the posterior part, consisting of the spinous and transverse processes—the laminae and articular facets—is a dense, hard bone and acts as a protection to the spinal cord, offers attachments for the muscles of the trunk, and goes to make up the joints between the individual units. Between each vertebral body there is a dense pad, the intervertebral disc, composed of fibrocartilage, and this disc is much more complicated in its structure than we were formerly led to believe. Injuries of it play a definite part in the symptomatology of spinal injuries.

All levels of the spine are subject to fracture. Fractures of the low dorsal and lumbar region are more numerous, but those involving the cervical region are much more dangerous as to life and permanent injury resulting in paralysis.

Fractures of the spine may be simple or comminuted. A single vertebra may be broken, or several in the same accident, and they may be at levels separated by uninjured vertebrae.

Fractures of the spine may be complicated by paralysis or paresis, but not necessarily so, so that the absence of paralysis is no criterion that a fracture is not present. It is of the greatest importance that careful histories be taken with special reference to the mechanism of the injury which would give suspicion of a fracture.

Taking of the History in Suspected Vertebral Fractures. The mechanism of the

injury is of great importance. Most fractures of the spine are of the compression type, and are produced by a flexing force—the writer, this latter method of causing the simple compression fractures has been by far the most common.

Fig. 1.

Fig. 2.

Figs. 1 and 2. Comminuted fracture of the first lumbar spine with marked lateral displacement. The patient became paralyzed after admission to the hospital. The successful use of the Goldthwait frame in the treatment of Potts' disease and the relief of paralysis resulting from it, caused us to use it in this case in the hope of realigning the spine and relieving pressure on the cord. The patient was put on the frame, traction and countertraction made, and slight hyperextension done to help reposition of the fragments. A plaster jacket was then applied. Within a few hours after being returned to bed, the patient showed return of movement in the legs, and eventually he made an excellent functional recovery. A reduction can thus be obtained by this very simple method in a badly fractured spine with accompanying paralysis.

The knowledge gained through this experience decided us to apply the same method in compressed and impacted fractures. The first compression was reduced six weeks later.

a quick bending forward of the body—either in the sitting or standing position. It may be a direct force such as a fall from a height or being struck from above by a force, while the spine is in a flexed position. Or it may be an indirect force, where the body is thrown forcibly into a flexed position, such as when riding in an automobile where the car goes over a dip in the roadway and causes a sudden flexion force of the upper portion of the body—in common parlance, the result of going over a "thank-you-ma'm." In the experience of

Comminuted fractures and fractures with lateral displacement are usually the result of a direct blow or a twisting force, such as one would experience in a railway accident, falls from a height, or the turning over of an automobile.

In cervical fractures, the mechanism is somewhat different, due to the greater amount of flexibility. Fractures of the neck occur at a high or a low level, depending on whether the producing force is received with the head flexed or hyperextended. If the force is delivered in hyper-

extension, the fracture is most likely to occur in the atlas or the axis; whereas if the head is flexed, it is likely to be in or below the third cervical vertebra.

Fig. 3. Fracture of the atlas and axis with extensive lateral dislocation of the atlas on the axis and with the odontoid process fractured and widely separated from its base. Notice the shift to the left of the atlas of about half the surface of the articular facets.

Fig. 4. Split-off fracture of the anterior portion of the body of the axis. The narrowing of the space between the bodies of the fifth and sixth vertebrae indicates an injury to the intervertebral disc with degenerative changes.

The symptoms of the simple compression vertebral fractures may be so slight as barely to cause complaint; whereas, the more severe fractures may be accompanied by paralysis and unconsciousness, and are not infrequently associated with skull injuries.

In the simpler form the following conditions may be present, but not necessarily all present in any one case:

1. Localized pain in the spine at the level of the fracture.
2. Muscular rigidity in the spine.
3. Reduced flexibility of spinal movements at level of injury.
4. Abdominal tenderness and abdominal rigidity in the low dorsal and lumbar fractures.
5. Girdle pains.
6. Prominence of a vertebral spine, a kyphos.
7. Inability to stand normally erect.

In the more severe and complicated fractures, neurological symptoms are present, such as nerve root pressure with sensory disturbance and partial or complete paralysis—the result of cord pressure or destruction. If paralysis is complete and instantaneous, the cord is probably severed (an important point to be remembered); whereas, if the paralysis comes on more slowly, it is likely to be the result of pressure such as bone displacements, bone fragments, or, if more gradual in its onset, the result of pressure of hemorrhage or edema. A carefully taken history of the onset of paralysis is of great value in the diagnosis and for the procedure of treatment.

EMERGENCY TREATMENT OF SUSPECTED SPINAL FRACTURES

Much good can be accomplished by a continuous campaign of education as to the care of the injured by those rendering first-aid. Much of the time, this first-aid is handled by totally inexperienced people, and of late this is especially true of automobile accidents. So it behooves us to see that our educational campaign reaches those who are most apt to render first-aid,

namely, the public. In such injuries as broken necks and badly damaged spines with lateral displacements, cord damage, even though it may not yet have occurred, can readily result from careless handling. Far too often are injured people literally dragged from an automobile wreck at tremendous risk of injury, whereas if they could be left until sufficient help arrives and moved with due regard for the possible injury, many less casualties would result. A firm non-sagging stretcher is recommended, and as little time lost as possible, with direct delivery to the hospital where the patient is to be treated. It is becoming far too common a practice to have injured persons carried to a police station, then to an emergency hospital, and then another move to put them into the hospital where they should have been taken directly from the scene of the accident. Eventually, when such a régime becomes universal, a much lower rate of permanent damage will result.

Fig. 5. Fracture of the lateral ring of the atlas. The margins of frayed spongiosa and the displacement distinguish this from the developmental hiatus occasionally found in this region.

The first thing to do is to get a clear statement of the nature of the accident: next, of what the injured notices as to his symptoms—that is, the location of his pain, his ability to move his extremities, and whether or not he notices sensory disturbance, such as girdle pains, hypersensitiveness, or numbness. Next, verify his statements and make a cursory examination. Then get a proper *x*-ray examination, to include lateral and stereoscopic anteroposterior views. If neurological symptoms are found, a detailed neurological examination should be done immediately and findings recorded. A summation of the findings is then made and the method of care decided upon.

Fig. 6. Fracture of the body of the second cervical vertebra, shown by a cortical defect at its anterior surface. Separation at the base of the lamina of this vertebra, presumably also fractured. The possibility of a developmental failure of fusion must be considered.

The method of treatment is given in detail under the heading of the classification in which it falls.

Injuries of the Nerve Roots and the Cord—As Complications of Spinal Fractures

In every spinal injury where fracture is suspected, cord or nerve root damage must be suspected.

In cases with extensive paralysis and sensory disturbance, cord damage is evident. In such cases it is a question whether the cord has been completely severed, partially severed, contused, or compressed from without. The differentiation is of great importance in determining the type and extent of treatment to follow.

The following table will show some of the more important symptoms:

Complete Cord Lesions	Partial Cord Lesions	Pressure of Cord from Without
Sudden onset of symptoms. Immediate and complete symmetrical sensory and motor paralysis.	Sudden onset of motor and sensory paralysis. Irregular.	Late in onset—few hours. Variable location of motor and sensory paralysis.
Muscles flaccid.	Muscles often spastic.	Muscle tone quite apt to be preserved.
Sensation entirely gone. Sharp line of demarcation.	Some sensation present, irregular distribution. No sharp line of demarcation.	Very irregular sensory disturbance.
Reflexes—knee jerks. Plantar reflex gone entirely.	Exaggerated tendon reflexes, or irregular.	Reflexes disappear slowly and return with relief of pressure.
Paralysis of bladder and rectum.	Paralysis of bladder and rectum not always present. Dependent on location of injury.	Paralysis of bladder and rectum much less apt to occur.
Priapism, sweating, involuntary muscular twitchings are common.	Priapism, sweating, involuntary muscular twitchings variable.	Priapism, sweating, involuntary muscular twitchings much less apt to occur

In those cases with a complete cord severance nothing whatever can be done. Laminectomy is not indicated.

In the cases where the examination shows partial severance, laminectomy may be indicated, depending, however, upon what the *x*-ray film shows as a possible cause of the cord injury. If due to splinters of bone, laminectomy may well be advised. If the symptoms of nerve or cord damage come on slowly, it is fairly certain that they are due to pressure. Such pressure may be from slight misplacements, which are so frequently found in compression fractures, or they may be a result of pressure from bone fragments, or from more gross bony displacements. There may be an acute angulation of the spinal canal with constriction, resulting in edema of the soft tissues, and localization of hemorrhage.

In all cases where a misplacement of bone could in any way account for neurological symptoms, the patient should be given the benefit of a manipulative reduction, as in most instances the pressure can be relieved and the symptoms cleared up.

The Treatment of Cases with Nerve and Cord Symptoms. Treatment of these cases should never be undertaken until every precaution is taken to satisfy the surgeon as to the cause of the paralysis, and the procedure of the manipulation and fixation planned to suit the individual case.

A very detailed description of reductions of the fractures at the different levels is given, and if followed out with the detail with which it is presented should be most helpful in handling this type of case.

We are indebted to Böhler for the method of reduction of cervical fractures. Key and Conwell make a special point of the value of using the Queckenstedt test to determine definitely whether pressure on the cord exists, and are guided largely by its results in advising laminectomy. (Key & Conwell, "Fractures, Dislocations, and Sprains." 1934. Page 304.)

The Care of Paralytic Patients. The following method of treating paralysis due to spinal fractures seems based on good logic and is recommended:

1. As soon as possible correct the bone deformity. (See method of treating Fractures with Displacement.)

2. Apply a properly supporting cast, well padded, and split into anterior and posterior shells if for complete paralysis.

3. Avoid all possible pressure of cast, which the mere weight of the body sometimes causes. The heels as they rest on the bed are to be very carefully guarded.

Keep the limbs in a neutral position and prevent contractions by splints, or preferably by skeletal traction.

Fig. 7. Reversal of the normal cervical curve suggests an injury due to a flexion force. This is found in the compression fracture of the body of the sixth cervical vertebra. The angulation between the third and fourth vertebrae would indicate an undiagnosed injury at that level.

Fig. 8. An anteroposterior view of a fracture of the lamina of the right side of the fourth cervical vertebra. Notice a considerable displacement of the entire lateral mass with dislocation of the entire facet.

Fig. 9. A lateral view of the case shown in Figure 8. Notice the anterior displacement of the body of the fourth cervical vertebra. This occurred as a result of a break in the posterior ring which allowed it to slip forward. This cannot occur if the posterior ring is intact and if there is no dislocation of the articular facets.

Fig. 10. Another lateral view of the same case, showing a perfect lateral alignment after reduction by traction and the application of a plaster cast from the hips to the occiput.

4. Turn patient frequently to prevent pressure sores, at least twice daily, and give immaculate care to all skin areas.

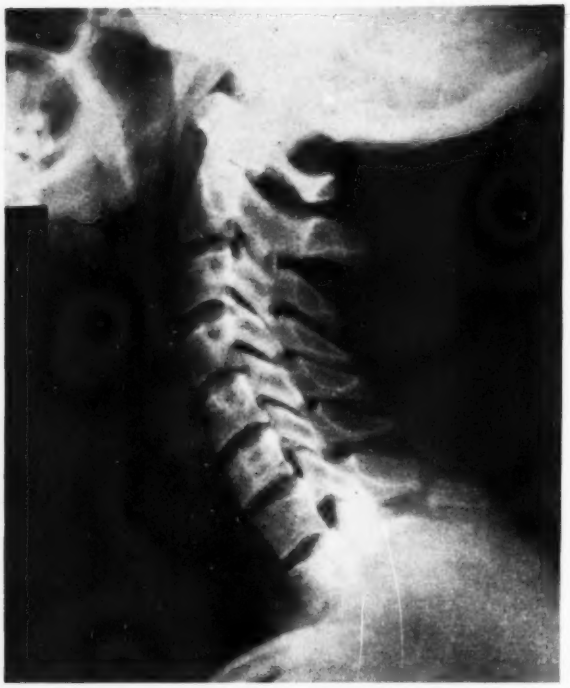


FIG. 11. Fractures of the spinous processes of the seventh cervical and first dorsal vertebrae as a result of muscular action.

5. Bladder and rectal care:

Catheterization must be most carefully done under the strictest aseptic conditions. Paralytic bladders easily become infected, and when infected are one of the chief causes of death. The bowels should be cleansed daily by enema.

FRACTURES AND DISLOCATIONS OF THE CERVICAL VERTEBRAE

Fractures of the neck are of two distinct types: the result of falling on the head, such as falling from a height or diving into shallow water; or, more rarely, of a direct blow on the head.

A. Hyperextension fractures:
When the force is delivered with the head in hyperextension, the injury is more likely to be to the atlas or axis.

B. Flexion fractures:
When the force is delivered with the head flexed, the injury is more likely to be from the third cervical vertebra down.

Of all spinal fractures, those of the atlas and axis are the most apt to result in cord injury.

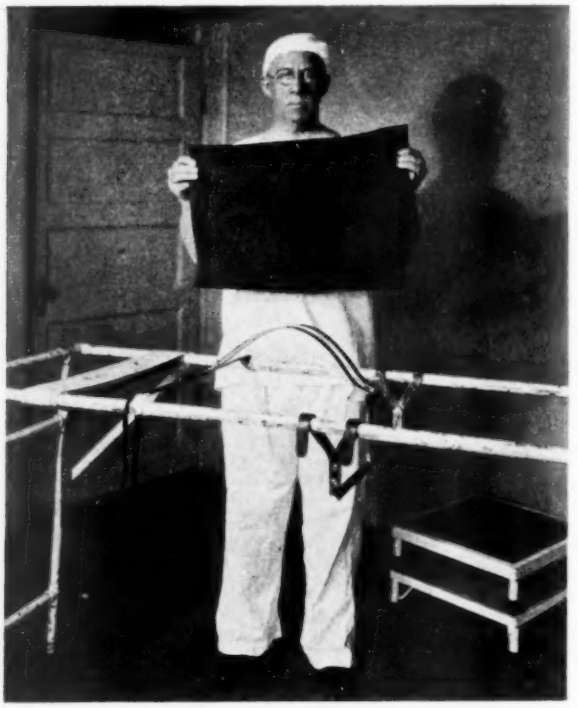


FIG. 12. Method of reduction. Hospital type of Goldthwait frame. This is attached to an ordinary gas-pipe frame. The two curved bars are the important elements. They are bent for each case, in order to bring the highest part of the curve just under the fractured spine, which has been compressed. The bars are made of spring steel, so tempered that they will remould the spine of a heavy man; it is essential that their flexibility be perfect. The felt pad is placed on the bars, to be included in the cast. The latter is applied as the patient lies on the bars after the successful reduction. The split in the felt pad is to relieve the pressure on the spinous processes.

A portable Goldthwait frame is quite satisfactory. The bars are interchangeable with those of the hospital type.

The fractures of the atlas occur most frequently through its weakest point, which is just posterior to the articular facets. Such fractures result in a separation of the fragments, and an increase in the anteroposterior diameter of its ring-like form. This allows the underlying axis, with its odontoid process, to be wedged upward between the fragments of the atlas, thereby menacing the cord by pressure.

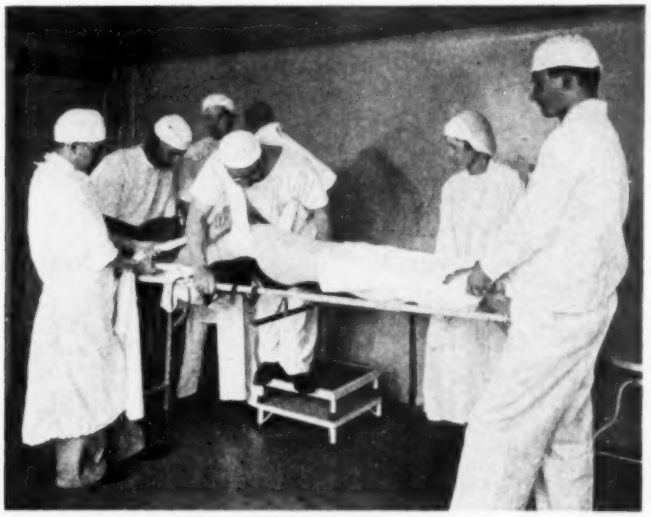


FIG. 13. One of the methods of producing hyperextension. The patient is placed on the Goldthwait frame. He is balanced by one assistant who holds the legs, and by two others who balance the shoulders by means of a folded sheet passing to the opposite axilla. A folded sheet is passed under the body at the level of the fracture and is tied over the shoulders of the operator, who then lifts the spine into the amount of hyperextension necessary to pull out the impaction of the vertebrae. When this is accomplished, the patient is lowered to the bars of the frame and an *x*-ray film is made to note the success of the maneuver and of the moulding of the spine on the frame. If the result is satisfactory, the plaster cast is then applied without further moving the patient.

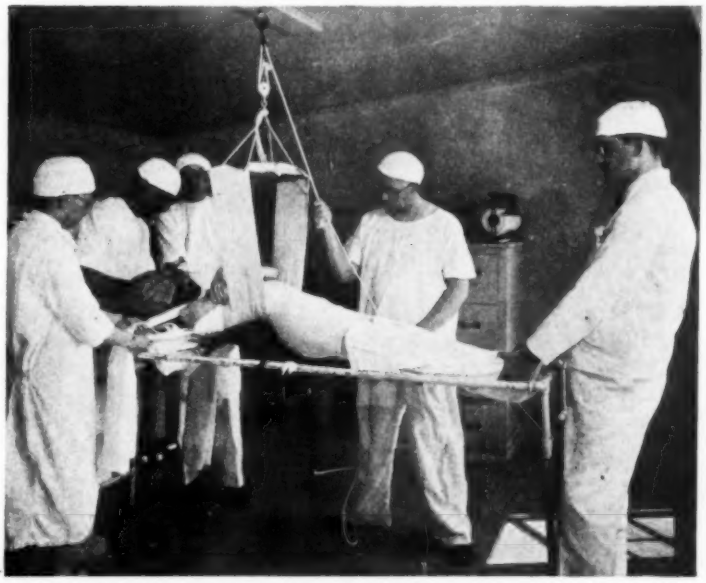
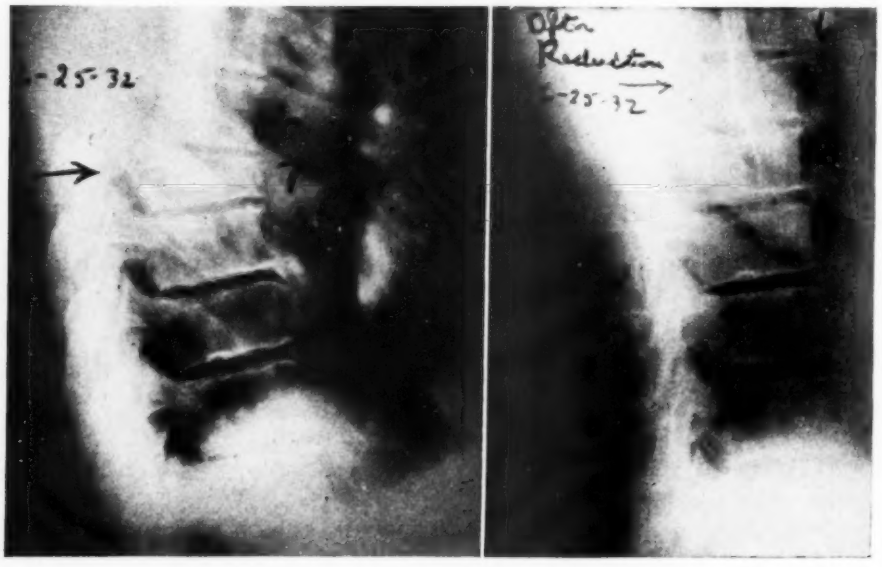


FIG. 14. Another method of producing hyperextension, devised by Dr. John Wright of Pasadena, California. It is easier on the operator in controlling the amount of hyperextension. In other respects it is exactly the same as the method indicated in Figure 13.

FIG. 15. This case is of special interest since it represented our first attempt to apply the method of forcible hyperextension and remoulding on the Goldthwait frame after the successful result with the patient shown in Figure 1. In this case note that the second lumbar vertebra was impacted from below.

FIG. 16. Same case as Figure 15, showing complete reduction of the impaction. The reduction was done October 10, 1927 and the above film was taken sixteen months later, on February 11, 1929. The successful outcome of this case resulted in the adoption of the method here described.



A B

FIG. 17. These films are remarkable in that they show a compression of the body of the seventh dorsal vertebra. A, before correction. B, complete restoration of normal contour. In a large series this was the only successful reduction at so high a level, and was obtained by very forceful hyperextension with counter-pressure.

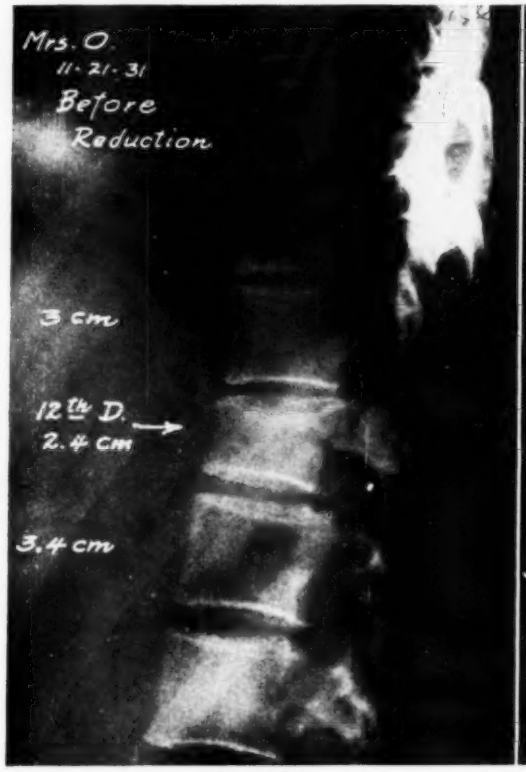


Fig. 18. Fig. 19.

Fig. 18. Simplest form of an impacted fracture of the twelfth dorsal vertebra, before reduction. The area of impaction is shown by an increased density of the upper portion of the body of the vertebra.

Fig. 19. Same case after reduction. The twelfth dorsal vertebral body has been restored to its normal form and the density due to impaction has disappeared. This film was made through the plaster jacket three days after reduction to verify the position which must be maintained throughout convalescence. (A check-up *x*-ray film should be made with the patient in the cast, as soon as the plaster jacket is dry.)

Fig. 20. A common type of compression fracture, before reduction. Notice the mal-alignment due to a forward displacement of the tenth dorsal vertebral body. Also notice the bulging backward of the compressed body with corresponding narrowing of the space of the spinal canal.

Fig. 21. The same fracture after reduction. Observe the perfect realignment and full restoration of the normal shape of the eleventh dorsal vertebral body. This was accomplished by slight forcible hyperextension to loosen the impaction, and remoulding of the spine on properly curved bars of a Goldthwait frame.

Fractures of the axis likewise occur just posterior to, or through, the articular facets, and the odontoid process may be broken off and act as a loose fragment, endangering the cord.

Fig. 22. Before reduction. This demonstrates that a number of vertebrae may be fractured with intervening vertebrae escaping injury. The shadows of impaction are very clearly shown.

Fig. 23. After reduction. This case demonstrates how beautifully reduction can be obtained by using the method of forcible hyperextension to release the impaction and then remoulding the spine on the Goldthwait frame. It will be noticed that even though the superior plate of the fourth lumbar vertebra is broken, and apparently not all of the impaction of this comminuted fragment released, the remoulding of the body is exceptionally good.

However, though all fractures of the atlas and axis do not cause cord severance, rarely does such an accident occur without some permanent cord injury. Where there is a complete cord severance it results in death or in immediate and complete paralysis of the legs, bladder, and rectum, accompanied by a flaccid priapism; there is also a weakness of the arms. Death usually ensues within a few days or weeks, preceded by a high rise of temperature. If symptoms of complete cord severance are not present, much good can be accomplished by an early reduction and realignment of the fragments.

Fractures of the lower part of the neck from the third vertebra down are more apt to be in the bodies of the vertebrae, and are frequently associated with fractures of the articular facets and the posterior ring, and accompanied more or less by dislocation of the articular facets. It is this comminution and dislocation which causes cord and nerve root injuries, and also makes reduction difficult.

Symptoms of Fractures of the Cervical Spine:

1. Pain, local and referred.
2. Local tenderness.
3. Muscle spasm.
4. Abnormal carriage of the head.
5. Sensory disturbances, especially of the arms.

6. Paralysis, variable, depending on the amount of injury.

Treatment of Cervical Fractures. Divided into two Groups.

1. Hyperextension fractures, those involving the atlas and axis: reduced by traction combined with flexion.

2. Flexion fractures, affecting the third, fourth, fifth, sixth, or possibly the seventh cervical vertebrae: reduced by traction combined with hyperextension.

Method of Reduction.

Previous to the reduction, all necessary material should be assembled, and a sufficient number of assistants to perform the work properly.

The Material Necessary:

1. A table with shoulder supports, preferably one which can be lowered at one end, so as to allow for application of the cast to the trunk when supported on a thin narrow board.

2. A thin, narrow board, to support the body and neck up to the head.

3. A Glisson sling.

4. Block and tackle.

5. A spring balance.

6. A hook in the side wall or a door knob, or any other fixed point to which the block and tackle may be attached.

7. Stockinet of sufficient length and size to cover the body from the pelvis to the top of the head, and of the proper width for the particular individual so that it will fit snugly. It is best to use a separate and smaller piece of stockinet for the head and neck, which may be sewed later to the larger piece used for the trunk.

8. Felt padding approximately a half inch in thickness to pad the top of the shoulder, occiput, chin, and upper portion of the chest.

9. A portable *x*-ray machine.

After this material is assembled, the patient is placed on the table and anesthetized. Böhler insists on local anesthesia, and it is of great advantage, especially in cervical fractures where the condition of the patient can be more accurately observed. When the anesthesia is complete, the head being carefully held, preferably by the surgeon or his assistant, the patient is arranged on the table with the supporting thin board and shoulder supports of the table in place. At this point, both the head and body portions of stockinet are put on, so that there will be no disturbance of the position of the patient after the reduction has been accomplished. The stockinet for the neck and head should be so rolled up that there may be free access to the neck during the reduction. The Glisson sling and spreader are then placed, and to it are attached the block and tackle with the spring balance between—the block and tackle then attached to the hook in the wall. All is then set for the reduction. Traction is now gradually applied with the operator palpating the area of fracture with the forefinger of each hand, the head being constantly held by the surgeon or assistant, who has held it throughout the preparation. The reduction of the fracture and the restoration of alignment will be felt to take place when sufficient traction has been applied. This will occur between 15 and 35 pounds' pull. Traction is then slowly let up to a few pounds' pull and with the patient still in this position, lateral and anteroposterior *x*-ray views are made. In fractures of the atlas and axis, in addition to the traction, the head and neck may have to be flexed for the best reduction; whereas, in the fractures below the axis, it is necessary to combine hyperextension with the traction. These movements are to be done by the surgeon who is holding the head during the time traction is applied.

When the reduction is found to be satisfactory, preparations for the application of the fixation cast are begun. From this time on, the head of the patient must be held firmly by the surgeon who will be responsible for the final success of reduction. The supporting board for the neck and chest is now drawn up into position and the Glisson sling removed, the neck and body portions of the stockinet sewed together to fit as snugly as possible, the

felt padding placed above the shoulders under the occiput and chin and over the upper chest, and the application of the plaster begun. Previously made plaster reinforcements will facilitate the application of the cast after the initial layers of plaster are in place.

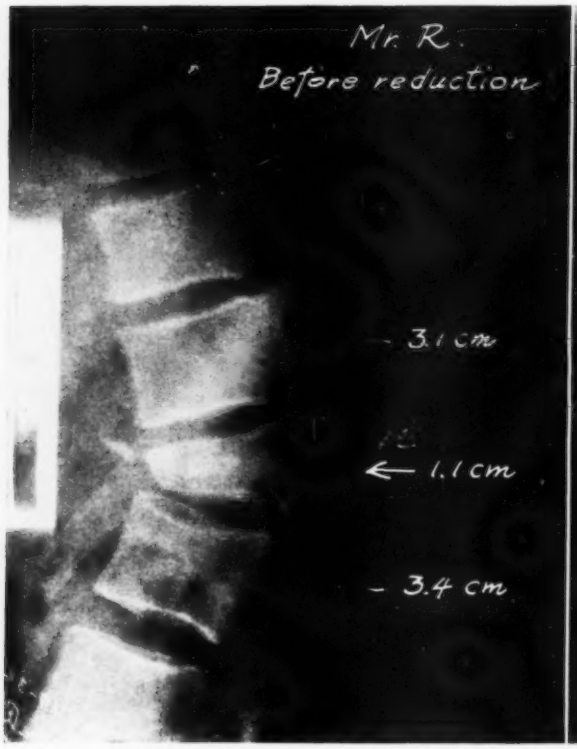


Fig. 24. A severely compressed and impacted fracture with a sharp kyphos and extreme mal-alignment. Before reduction.

Fig. 25. Same case after reduction and remoulding on the Goldthwait frame. Note the complete reduction of the kyphos and excellent realignment of the spine as a whole. The firm attachments of the bone to the anterior longitudinal ligament and to the discs must play an important part in bringing the fragments into position.

In fractures of the atlas and axis, the cast should include the head, for more positive fixation. In fractures below this area, the head portion may be left off, but a very accurate moulding about the occiput and chin are necessary. The jacket portion of the cast should be sufficiently long, preferably to the crest of the ilium.

After-Treatment of Cervical Fractures. If paralysis is present, a long period of bed treatment is necessary, special care being used to avoid contractures and deformities. Properly fitting splints, avoidance of pressure of bed clothes, and the use of traction to the limbs, are in order. In paralysis, the skin does not take kindly to skin traction, so skeletal traction should be used. Always splint or apply traction with joints in a neutral position avoiding strain. In those cases where paralysis is not present and sensory disturbances slight, the patient should be allowed to get up, and encouraged in normal activities. Healing of the bone and soft tissues requires from three to six months. The cast must be worn during this entire period of healing. Post-operative *x*-rays should be taken at first at two week intervals following the reduction, and always at the time of removal of the cast to see that healing is complete. During this period, if recurrence of the deformity has occurred, realignment should be repeated.

At the end of the cast-wearing period, a gradual return to normal life and activity is advised. If good stability is not present, a

support is advisable, such as a leather collar to be worn up to a year following the injury.

Fig. 26. Marked compression of the vertebral body of both the anterior and posterior surfaces before reduction. There is a backward displacement of the entire posterior surface of the second lumbar vertebra, with resulting narrowing of the spinal canal. Note its mal-alignment, with the bodies of the vertebrae above and below.

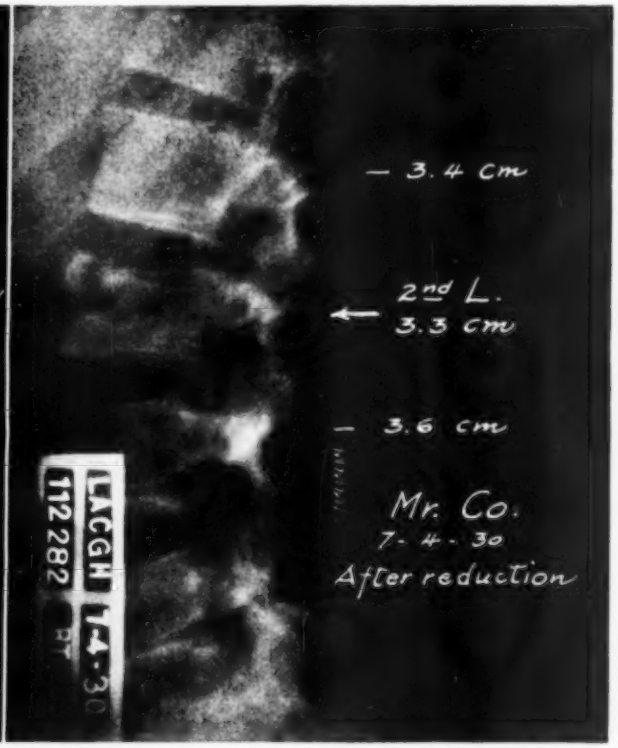


Fig. 27. Same case after reduction and remoulding on the Goldthwait frame. Note the excellent realignment of the posterior border of the body of the second lumbar vertebra. Also the repositioning of the fragments of the comminuted body with fair restoration of its original height. Excellent bone repair was obtained to maintain the correction following sixteen weeks in cast, flat in bed, followed by eight months of wearing a Taylor-type back brace.

Heat, massage, and graduated exercises will help an earlier return to activity.

FRACTURES OF THE DORSAL AND LUMBAR VERTEBRAE

Fractures of these two areas are grouped together because of the similarity of types and their causes. Most fractures of the dorsal and lumbar levels are produced by a forcible flexion of the trunk, and cause a compression and impaction of the vertebral bodies. This force is not so readily applied high in the dorsal area, but as the force is applied lower, fractures become more frequent. The areas of greatest flexibility are those most subject to injury, from the tenth dorsal to the fourth lumbar. Statistics show that the greater number occur at the twelfth dorsal, and the first and second lumbar. In the simpler form, the body of a single vertebra is compressed, as shown in the film of a lateral *x*-ray. From an antero-posterior view, one side or the other may be more compressed, depending on how the force was applied, as it might be with a twisting or bending of the body. The antero-posterior *x*-ray view may or may not show, or show with difficulty, a simple compression fracture; so it is of the utmost importance to obtain good lateral *x*-ray views of the entire spine when suspecting fractures.

In addition to these cases of simple compression fractures there may be those with chips off the anterior surface, those where

the vertebral body is split in any angle, and those where considerable fragmentation of the vertebral body has occurred. Also, and of the greatest importance, are those where fractures may occur with lateral displacement and with considerable over-riding of the fragments.

FIG. 28.

FIG. 29.

FIGS. 28 AND 29. Anteroposterior and lateral films of an uncorrected compression fracture which has healed by bony union to the vertebral bodies above and below. This type of healing does not occur in well reduced cases.

COMPRESSION FRACTURES OF THE SPINE

By far the greater percentage of spinal fractures are compression fractures. A single vertebral body may be fractured; two or more adjacent bodies may be involved; or there may be isolated fractures at different levels with uninjured vertebrae between them. It is important to remember this latter possibility. It is essential to have the original *x*-ray examination include the whole spine, and to make a very thorough study of all levels.

Etiology and Pathology. The cause and effect of the forces producing compressed and impacted fractures are inseparable. Any force so applied as forcibly to flex or laterally bend the trunk may produce a compression fracture. The nature of the construction of the vertebral bodies being formed of cancellous bone lend themselves to compression fractures. As force is applied to this cancellous bone, any of the following conditions may result:

a. A simple impaction with little or no change in its lateral or anteroposterior diameters.
b. A crushing or comminution which broadens the body of the vertebra laterally and anteroposteriorly.
c. A longitudinal split through the body of the vertebra with comparatively little compression.
d. A chipping of fragments from the upper anterior surface.
e. An injury to the posterior arch, such as the articular facets, lamina, and spinous processes, which may accompany any of the above fractures.
f. Injury of the intervertebral discs.

g. A tearing of the supporting ligaments and muscles.

Diagnosis of Compression Fractures. An injury of the spinal column should be suspected whenever the type of accident is such as is capable of producing it; and therefore, the detail history of the accident is of paramount importance.

The types of accidents most likely to cause these injuries are; a fall from a height with the body flexed; a sudden jounce in an automobile, such as going over a dip in the road. Frequently in the latter case the individual is only conscious of a slight pain in the back, and so continues the journey, often driving himself, and only seeking medical attention at the end of the journey because of the persistent pain. In fact, any accident, however slight, taking place with the back flexed, may produce a compression fracture; and it is now the common belief that many more occur than are ever recognized.

Fig. 30. Before reduction. Extreme lateral displacement and extensive paralysis which developed within a few hours.

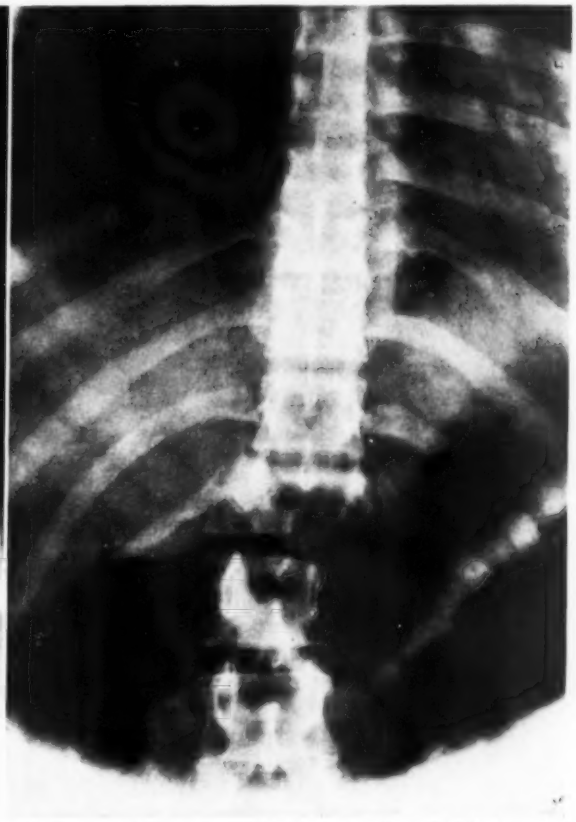


Fig. 31. Same case after reduction. Technique used was that employed in case shown in Figures 1 and 2. The Goldthwait frame was used throughout the remodelling process and was of the greatest help in assuring the safety of the maneuver. A perfect functional result was obtained.

In all suspected cases, a very thorough *x*-ray examination should be made. It is best to include a much greater area than just the suspected level. As the symptoms of localized pain are indefinite it is wise to include the entire spine.

Frequently there is localized pain on pressure over the spinous process of the affected vertebra. There may be girdle pains, or sensitive areas, as the result of pressure on the spinal nerves. Paralysis indicates cord or nerve damage or pressure, and is to be most carefully investigated as to its cause. Spasm of the spinal muscles is present as a protective measure, and abdominal muscle spasm may be present. Deep tenderness on abdominal pressure is not uncommon. A prominent spinous process is frequently found, but not neces-

sarily so, as its presence depends on the amount of angulation due to destruction of the vertebral body. A very thorough

Fig. 32. This is the only case in a long series of back injuries to show a transverse split in a lumbar spine. The question has arisen here as to whether or not a fracture of the lamina accompanies it. The small black arrow points to the line of fracture in the spinous process of the first lumbar vertebra.

neurological examination should be done in all cases, as the procedure of treatment and prognosis so largely depend on its disclosures.

Treatment of Compression Fractures of the Spine. Warnings as to Its Application. In determining the type and extent of treatment much has to be taken into consideration. In the simple uncomplicated cases of compression fractures, reduction by hyperextension with application of plaster jacket for fixation is in order; but a very careful study of the type of injury should be made previous to undertaking the reduction. The following conditions may influence the procedure of treatment:

1. A crushing fracture, where the posterior border of the body of the vertebrae is broken and protrudes backward, narrowing the spinal canal. This may be in the form of splinters of bone, which would be a warning against any undue roughness in handling the patient.

2. Accompanying fractures of the arch, and the fractures and dislocations of the articular facets:

These are becoming more frequently recognized by the use of oblique *x*-rays, which more clearly show the articulations. The usual antero-posterior and lateral views do not give a proper view of these structures. These cases require special consideration. The forceful hyperextension which is used in disimpacting the simple compressions is not applicable to such a complication.

3. Injuries of the intervertebral discs:

From a careful study of the original *x*-ray, one can often suspect damage to the disc by a lessening of the space between the bodies. At times, the post-operative film may give a clew of such damage by showing an abnormal widening of the space, especially if fixation has been in excessive hyperextension. Injuries to the disc cause a destruction of its contour, and may spread its contents in any direction. It has been demonstrated that symptomatically the most serious of such injuries is the protrusion of its mass posteriorly into the spinal canal, causing spinal cord irritation and compression.

4. Compressed and impacted fractures high in the dorsal area are very difficult, and sometimes impossible, to reduce. Above the seventh or eighth dorsal seldom has a change been obtained in deformed bodies of the vertebra by hyperextension. As the level of the fracture approaches the tenth dorsal, more correction is possible. From the tenth dorsal down to the fifth lumbar, the force can be so directly applied that full restoration of the height of the body of the vertebra is attainable.

The reason for this is that the upper levels are too protected by the chest wall to permit of change.

5. The question always arises as to how soon after the injury the manipulative reduction should be done.

The answer is: As soon as the condition of the patient warrants. The average compression fracture is accompanied by very little shock, and nothing can be gained by delay.

As in all fractures, replacement of fragments is very much better if the reduction is done before the onset of swelling, coagulation of the hemorrhage between the fragments, and contraction of the muscles. It is much easier for the surrounding soft tissues to mould the fragments of bone into their normal alignment.

In the writer's experience there has been increasing difficulty in reducing the impaction if too long a time has elapsed. It is well to allow the patient to recover from shock. On one occasion* a reduction was effected three weeks after the accident, but on other patients attempts at the end of ten days were unsuccessful.

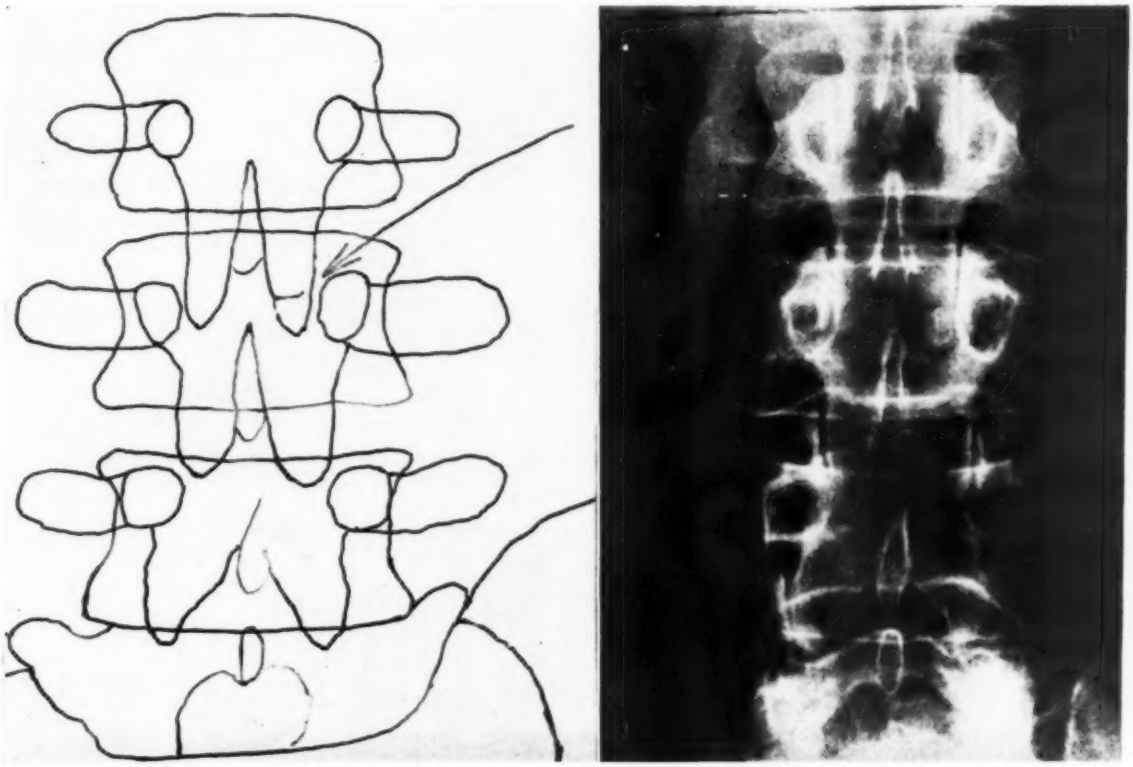


FIG. 33. Anteroposterior *x*-ray film and line drawing showing a fracture of an articular facet. This is differentiated from a congenital fault in fusion by the irregularity of the edges of the fracture line, and also by the presence of a small extra fragment. (*Courtesy of Dr. Wilbur Bailey.*)

The Technique of Reduction of Compressed and Impacted Fractures. It is generally conceded that hyperextension of the simple compression fractures realigns the spine if there is no fixation from impaction. If there is impaction, some force is necessary to disimpact it. If the case is seen early, before partial healing of the fracture has taken place, the impaction is disengaged with very little force—perhaps slight traction combined with hyperextension, such as is used by Davis when the body is hyperextended by swinging the patient up in the prone position, lifting the legs and bowing the spine backwards. This is readily done by tying a rope about the ankles and elevating the legs to the neces-

* Delay was necessary to allow the patient to recover from pneumonia.

sary height to produce the desired amount of hyperextension. In this way, the body weight produces a traction force frequently sufficient to disimpact. Another way to accomplish the same result is the method of Watson Jones, in which the upper portion of the chest is lifted rather than the legs. In these methods the cast is applied with the patient still strung up as he is for the reduction.

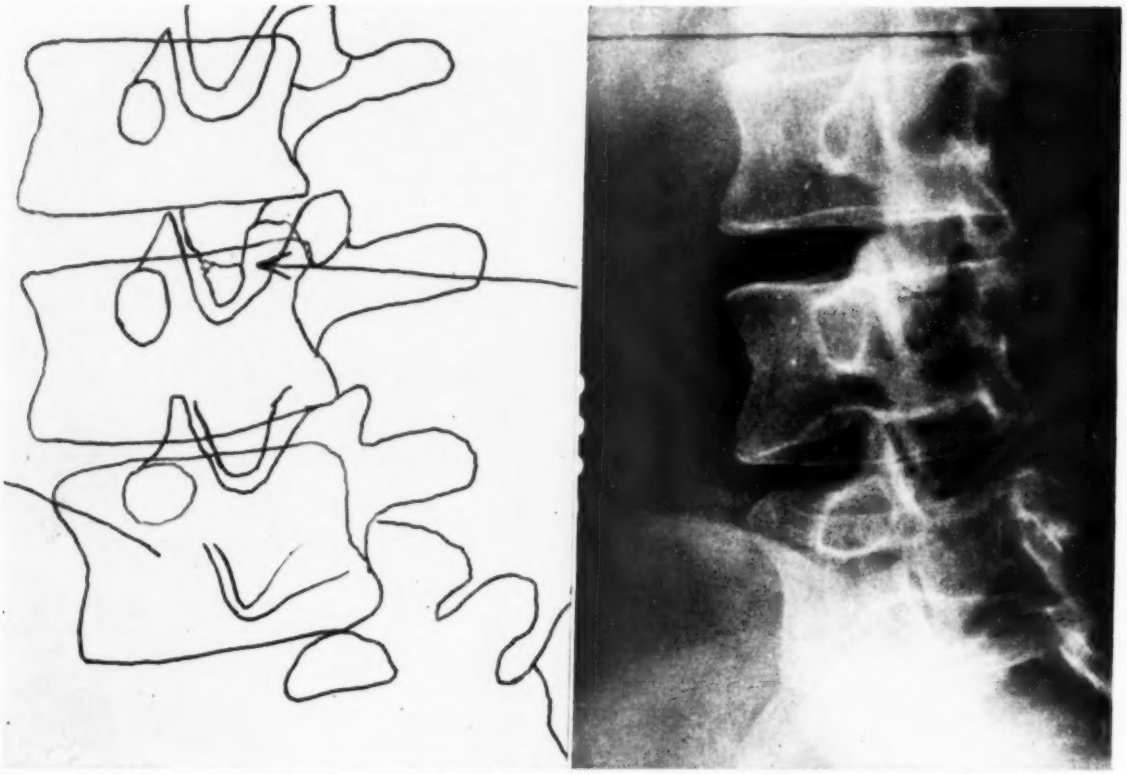


Fig. 34. Oblique *x*-ray film and line drawing of same case as shown in Figure 33. (*Courtesy of Dr. Wilbur Bailey.*)

A simple way to reduce an impaction is as follows:

1. Place the patient on an ordinary flat topped table and enclose his entire trunk in a snugly fitting stockinet, inside of which have been placed lengths of muslin bandage to be used later as leaders for gauze scratches.

2. Anesthetize the patient. Avertin and gas is suggested.

3. Have one assistant balance the legs, and another balance each arm.

4. The body is then carefully brought into the desired amount of hyperextension. This hyperextension force can be accomplished by grasping around and under the body with the arms. It is made easier by the use of a sling and block and tackle, or by passing a folded sheet beneath the body and tying it over the operator's shoulders. In any one of these methods the operator can easily judge the amount of force being applied. Experience has proven that in the average case very little force is required.

5. After sufficient hyperextension has been done, and while the patient is still held in hyperextension by the operator, the padded Goldthwait frame is placed in position and the patient lowered onto it. The irons of the Goldthwait frame are bent previous to the manipulation so as to bring the height of the curve just at the level of fracture. As the patient settles on the frame, the spine automatically is moulded into its correct alignment.

6. A lateral *x*-ray film is then made to determine the exact relation of the realigned fragments.

If the correction is not satisfactory the hyperextension is again applied. Seldom more than two or three attempts are necessary if disimpaction is possible, and experience will show that very little force is required.

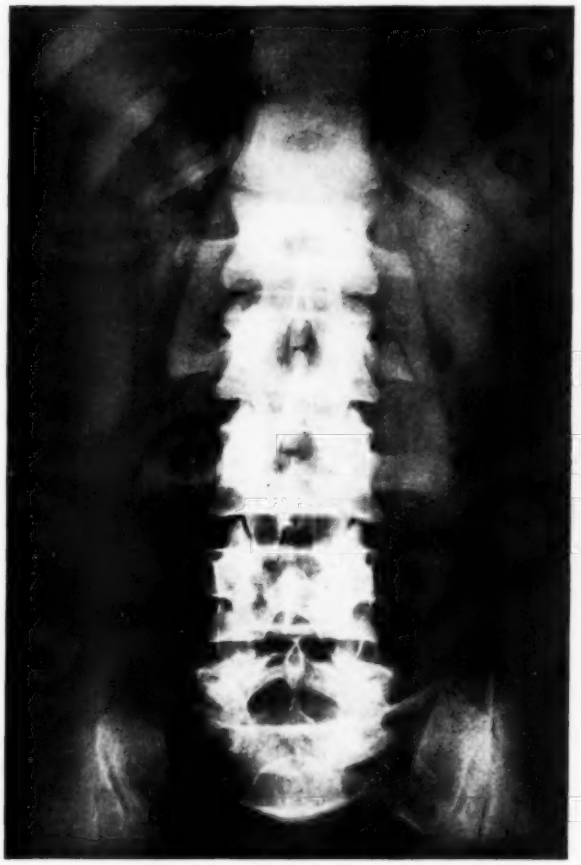


Fig. 35. Two adjacent transverse processes fractured, with very little displacement. Treatment by keeping the patient flat in bed for seven weeks resulted in union.

7. When a satisfactory position is obtained, a plaster of paris jacket is applied with the patient still on the Goldthwait frame. This will include the heavy felt pad which has been placed on the bars, and on which the patient lies. Other bony prominences are padded with thin felt. The jacket should extend from the neck to the pelvis.

8. When the cast has set, remove the patient to a table or cart with a pillow under the hollow of the back. Trim the cast for comfort and utility. Turn patient on side and slip the steel bars out from the cast.

It is advantageous to cut a window in the front of the cast just over the epigastrium. This was first done to allow for abdominal examination and was found to be very helpful as a safety measure in abdominal distension.

Fig. 36. A most interesting case showing numerous types of injuries. Multiple and bilateral fractures of the transverse processes of both the lumbar and dorsal areas, dislocation of the eleventh and twelfth ribs on the side of multiple fractures, and fractures of the tenth and eleventh ribs without displacement. There are also six lumbar vertebrae present in this patient. The displacement of the transverse processes is extreme; hope for reunion is nil.

The Principle of Reduction. The principle of reduction is that of traction with hyperextension. The moulding of the fragments into position is accomplished by the compression of the surrounding ligaments and muscles when put on tension; and the accuracy of reduction depends largely on whether or not the ligaments remain intact at the time of accident. The anterior spinous ligament is the greatest single force in accomplishing this remould-

ing. In the comminuted cases, a tearing of the ligaments and muscles is frequently present, and may account for incomplete reductions. The use of the Goldthwait frame is exceedingly helpful in accomplishing accurate reductions, and makes the application of the fixation cast much more simple. This is especially true where there has been a tear in the ligamentous structure, and also in those cases where cord pressure from misplaced fragments is suspected. With this firm support, a much more accurate remodeling of the injured tissues can be accomplished, and held during the application of the fixation cast.

The Use of the Goldthwait Frame. The Goldthwait frame was designed in the late nineties by Goldthwait and Metzger for the treatment of tubercular spines, to reduce the kyphosis through a series of plaster jacket applications, in the hope that a healing of the disease would take place when the irritation of pressure on the affected area was released. This was accomplished by separating the diseased areas by an increasing amount of hyperextension with each successive jacket application. It was noted that in those cases developing a paraplegia due to pressure on the cord from the knuckling of the spine, the paralysis cleared up, sometimes immediately, when the hyperextension was accomplished, even while the patient was still on the frame. It was with this understanding of its use that this frame was first used in a badly displaced fracture of the spine and slowly developing paralysis. From the very miraculous result obtained in realigning the fragments and the relief of paralysis, its application to use in the compression fracture cases was developed. The understanding of the use of this frame is simple. It merely moulds the spine and holds the body in any desired amount of hyperextension during the application of a plaster jacket.

The bars of the Goldthwait frame are made of flexible steel with sufficient tension to support the body weight in the desired amount of hyperextension during the application of the cast. Since these bars are flexible, account has to be taken of the amount of sag the weight of the body causes, so that the desired correction will be retained when the weight of the body is on them. They should be bent so that the highest point of the curve is as nearly under the site of fracture as possible, and this curve has to be changed for each individual case. If the bar is made of sufficiently malleable steel, this change is readily made. The only caution necessary is not to put the patient into too great hyperextension. The bars are free, merely resting on uprights to allow for passing of the plasters around the body during the application of the jacket. As soon as the plaster jacket is finished and set, the patient is placed on a table or bed, and the bars of the frame, on which the patient has lain, are withdrawn from the cast.

The Felt Pad. Its use is to properly pad the bars of the Goldthwait frame, and later to supply a comfortable rest on which the patient lies during his convalescence. It should be of sufficient thickness—one inch thick grey felt is suggested—and should be sufficiently long and wide to cover the entire back. An incision can be made in it longitudinally in order to relieve pressure over the prominent spinous processes. It will separate and adjust itself by the pressure of the protruding spines.

The Care of the Skin under the Cast. There should be placed between the skin surface and the stockinet one or two lengths of strong bandage, to be used as leaders to carry gauze strips which are later used to give the body a complete alcohol rub daily, to be followed by toilet powder. If this routine is strictly followed, the skin will be found in perfect condition at the removal of the plaster jacket.

Care should be taken each day to see that these gauze strips pass freely across the spine. If there is an obstruction, the skin has probably developed a pressure sore at the level of the highest point of pressure of the cast, where the greatest amount of leverage takes place. By avoid-

ing morphine one can tell when this pressure is taking place, by complaints of the patient. A narrow window about one inch in width will relieve pressure if it develops.

Paralytic Ileus. A small percentage of cases after reduction develop temporary ileus. The paresis of the intestines comes on within a day or two following the reduction, and usually lasts two or three days at most. It has been noticed likewise in those cases where reduction has been temporarily delayed. Its cause is not known, but it is probably due to trauma of the superior and inferior mesenteric ganglia at the time of the original accident.

In order to allow for the abdominal distension which accompanies this condition, a window is cut in the jacket over the epigastrium. This will also facilitate abdominal examination.

Accuracy of Reduction. Sufficient attention has not been given to accuracy of the reduction. Restoration of the full height of the anterior portion of the body of the vertebra, the compressed portion, is possible in the large majority of cases. If the Goldthwait frame is used for the moulding of the spine, with the patient on the frame and before the fixation cast is applied, the check lateral *x*-ray examination is made to discover if the correction is satisfactory. If the Davis or Watson Jones methods are used, this is done while the patient is strung up in the hyperextended position, and if the correction of the compression is found not complete, further hyperextension with added force should be done, and the *x*-ray repeated. This maneuvre should be repeated until satisfactory reduction is accomplished. Then, and only then, should the cast be applied. I repeat that perfect restoration of the normal height of the vertebral body is possible, except in those cases where: comminution is present; the expanding force of the intervertebral disc has injured the upper or lower plate of the body; or the anterior spinous ligament has been ruptured so as to lose its grasp on the fragment. In the latter instance, the moulding power of the Goldthwait frame is of particular assistance.

Post-Operative Care. There are two schools of thought. There are those who believe that the patient should be got up as soon as the plaster is quite dry, so as to prevent atrophy and weakness of the muscles and ligaments, the accuracy of holding the reduction depending on the great amount of hyperextension used in the cast and the accuracy with which the cast is moulded to the body. It is very closely fitted to the pelvis, lumbar region, and high over the manubrium, and is worn from five to six months.

The other school of thought, which includes the writer, keep the patient in bed, not even allowing him to turn fully on his side, and never on his face, and he must retain this position until such time as bony union is complete (fourteen to sixteen weeks). At the end of this time, full activity may be allowed, or a Taylor back brace may be used for a few months. The necessity for the use of the brace is questionable. An *x*-ray at the time the jacket is removed will disclose the condition of bone healing, and this should never be neglected. Reference is made by some authors to a bridging of bone which frequently takes place at the site of fracture. This bony bridge will not occur if the reduction has been accurate.

FRACTURES OF THE VERTEBRAE WITH LATERAL DISPLACEMENT

When fractures occur which entirely destroy the alignment of the spinal column and the articulations between the adjacent vertebrae, the problem of care is very different from that of the compression fractures.

In such cases, much crushing of the bones is present, and often no connection with the next vertebrae is retained. Often much lateral displacement and over-riding of the fragments is present.

Paralysis is present, and its amount depends upon the damage done to the cord and the spinal nerves as a result of the

tearing of the tissues accompanying the displacement.

If the paralysis is complete immediately following the accident, it would indicate a severance of the cord or nerve roots, or both. If paralysis comes on more slowly it is more apt to be due to a constriction of the cord or nerve roots caused by the contusion or pressure of bone fragments, or stretching as a result of displacement.

In such instances the patient should be given the benefit of the doubt by an attempt to realign the fragments, in the hope of relieving the pressure. Such cases have been quite successfully treated as follows:

1. Prepare the Goldthwait frame, and the pad on which the body is to lie, with special attention to the curve of the bars.

2. Lift the patient very carefully onto the Goldthwait frame, at the same time having a sufficient number of assistants to hold the legs and arms in as much traction as is possible.

3. After placing the patient on the frame, continue strong traction to legs and arms, or better still, with folded sheets under the axillae for traction. The operator then slowly and carefully lifts the body into hyperextension a few times to help bring the fragments into alignment.

4. An *x*-ray film is then made, both antero-posteriorly and laterally, to determine whether or not the realignment has been accomplished.

The moulding process may be continued several times by continuing the traction and lifting the body until the operator is assured that sufficient reduction has been accomplished to relieve pressure on the cord caused by bone fragments. At no time during the maneuvre should the patient be without the moulding power of the Goldthwait frame.

5. A plaster jacket is then applied, with the patient still on the Goldthwait frame, just as in the cases of compression fractures.

6. When the cast is set, the patient is removed from the frame, with the bars still within the jacket. One must be quite sure that the cast is sufficiently firm before these bars are withdrawn, as it is the position obtained by moulding the body on the bars upon which one must rely for the final position of the realigned fragments. It does no harm to leave the bars in position within the cast for a few hours.

It is astonishing how good a reposition of fragments can be thus accomplished. Frequently paralysis begins to clear up within a few hours after reduction. The residual paralysis depends upon the amount of permanent injury that has been done to the cord and nerves. Therefore the sooner the reduction is done, before the pressure necrosis takes place, the more likelihood there is of recovery.

Every case with paralysis should have the advantage of reduction, with the hope that permanent injury has not yet taken place.

FRACTURES OF THE CERVICAL SPINOUS PROCESSES

These fractures have been thought to be rare, but it is probable that they are not so rare as we have been led to believe. They are difficult to diagnose. Usually the sixth and seventh cervical and first dorsal spines are affected. Such fractures may be the result of indirect violence, as a forcible flexion of the neck, or they may be due to a direct blow at the lower portion of the back of the neck. Some believe they are due to muscle actions alone. The separated fragments of the spinous processes are drawn down from their normal position, usually with considerable separation and accompanying tearing of the dense ligamentum nuchae, causing a sulcus which can be palpated. One or more spinous processes may be involved. The head drops forward and cannot be fully extended, due to the tearing of the ligament. Localized pain is a very prominent symptom, and is persistent. The diagnosis is difficult owing to the difficulty of getting clear *x*-rays of this particular location.

If the separation of the torn ends of the ligamentum nuchae are so extensive as to interfere with proper erect carriage of the

head, an operation to repair the rent in the ligament is advised. During this operation, the loose fragments of bone may be removed, with special care not to do further damage to the ligament. It does no harm to leave these fragments in, whether they unite or not.

FRACTURES OF THE SPINOUS PROCESSES OF THE DORSO-LUMBAR REGION

Longitudinal splitting fractures of a spinous process are observed, especially in the lumbar region, accompanied by tearing of ligaments; and to a moderate degree, dislocation of the articular facets. In such injuries, one should be very suspicious of a more extensive lesion. Fixation in plaster in hyperextension should be all that is necessary, followed by an *x*-ray to see that the realignment has been accomplished. Suture of a separated spinous process with extensive soft tissue tearing might be considered for more perfect approximation.

FRACTURES OF THE ARTICULAR FACETS

Isolated fractures of the articular facets are difficult to diagnose. Suspicion of such a fracture is aroused by localized pain following a spinal injury when other gross lesions of the spine are not found. Special *x*-ray technique is required to show the facets clearly, especially the oblique views.

Plaster fixation for a period of ten weeks to three months is usually sufficient in the early cases. When the diagnosis has been made late, a fusion operation is more satisfactory.

FRACTURES OF THE TRANSVERSE PROCESSES

A single transverse process may be fractured, or any number, frequently several on one side; and both sides may be fractured at the same time. Fractures of the transverse process are usually the result of muscular violence, but may be the result of direct trauma. In the latter case, they are usually associated with soft tissue injury or even kidney damage. Since the function of the transverse process is wholly for muscle attachments, especially the psoas muscle, it is important to relieve the tension of the muscles on the fractured or separated process until such time as bony healing has taken place; or in those cases where the separation of the fragment is too great for bony bridging to take place, until the torn soft tissues have healed. Bed treatment is advised with special instruction to keep the legs quiet to prevent muscle pull on the detached fragments. A single transverse process has less tendency to become displaced and the treatment may consist of two to three weeks; whereas, if many are fractured, more displacement is apt to occur and a much longer period of rest is necessary—from four to seven weeks in bed. In cases where the separation has been so great that union has been an impossibility, pain may persist. No good can be accomplished by the removal of a transverse process which has failed to unite. It is not necessary to apply a plaster jacket to insure rest, which is the essential thing.

FRACTURE-DISLOCATIONS OF THE CERVICAL SPINE*

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A great number of spinal injuries is found in the cervical region where the most vital part of the spinal cord, both from the standpoint of life and function, is either affected or seriously threatened. The necessity for prompt recognition and careful supervision of these injuries is obvious.

In civil life, fracture dislocations of the cervical spine are almost always produced by indirect violence, consequently, these injuries are often associated with severe cerebral trauma. This fact not only adds to the gravity of the patient's general condition, but makes recognition of the spinal injury more difficult, and increases the risk of added damage to the spinal cord before treatment can be instituted. The conscious patient, because of pain, is likely to supervise his transportation in such a way that the injured parts are held immobile, thus preventing augmentation of soft tissue injury. However, when the state of consciousness is disturbed this protection is lost and as a result of careless transportation, complete destruction of the spinal cord at the level of the fracture dislocation may occur. The importance, therefore, of careful supervision of these patients cannot be overemphasized.

In recent years, through educational campaigns, the public has become more conscious of its first-aid methods, and ambulance operators have become more alert to their responsibilities, but on the whole, injured persons are still subjected to transportation methods which, though difficult to prove, are in all probability responsible for loss of life or permanent paralysis in many cases.

Pain and muscle spasm accompanying cervical injuries, cause the head to be held in a fixed position. Being a protective reaction, this position should be maintained until the extent of the injury has been determined. Any movement of the head, except possibly that produced by gentle traction under competent supervision, should be avoided.

Diagnosis: In the absence of typical neurological findings, the diagnosis is not always easy—hence many fracture dislocations of the cervical spine escape detection until after the patient has been discharged from the hospital. Regardless of the manner in which the patient is injured, persistent pain in the cervical region, with or without limitation of motion, is an absolute indication for Roentgen examination.

The diagnosis immediately presents itself when the patient shows a quadriplegia or paraplegia with a bilateral "lower arm" type of paralysis. Transverse cord lesions at or above C 4 cause paralysis of all extremities. Below C 5, upper arm function is spared. If function is preserved in the arms and hands, and abolished in the lower extremities, the lesion is below T 1.

In the conscious patient the level may also be determined by sensory examination, and only in the conscious, cooperative patient can the degree of cord injury be determined. That is, the differentiation between a severe partial and a complete transverse lesion. Loss of motor power indicates a severe injury, but if sensation in any form is retained below the level of the injury, continuity of the cord is established and motor function may return.

During the first few days the neurological examination should be repeated at frequent intervals to determine any change in the

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patient's condition. Signs of progressive loss of function must be recognized early if anything is to be accomplished by treatment.

On examination the first fact one wishes to determine is whether or not there is a complete transverse cord lesion, and, if so, if it were the immediate result of injury. Transection of the cord is unusual and cannot be recognized clinically, but physiological section, usually the equivalent of transection in civil injuries, is recognizable and is demonstrated in its early stages by total loss of all cord function below the level of injury. The findings are flaccid paralysis, loss of sensation in all forms, loss of both deep and superficial reflexes and often priaprism. Appearing immediately (excluding gunshot injuries), these signs are almost without exception indicative of a complete transverse cord lesion, from which there is no hope of regaining function. We have been forced to adopt this view inasmuch as we have never observed any neurological improvement in a patient presenting evidence of an immediately complete transverse lesion determined by the above criteria. The late return of reflexes and the lowering of the sensory level one or two segments, is of no real significance.

The term complete transverse cord lesion should not be applied to those cases presenting immediately any evidence whatever of cord function below the level of injury. The preservation of deep sensation, a tendon reflex or the demonstration of a Babinski sign should be regarded as an indication of a severe but incomplete lesion, offering at least some hope of improvement. Optimism on the part of some toward so-called complete transverse cord lesions has probably been based upon inadequate neurological study.

Involvement of nerve elements varies greatly—from pinched peripheral nerve roots producing pain in the neck, radiating down one or both arms. to complete transverse cord lesions with loss of life or permanent loss of function, Between these two extremes is a group of cases presenting signs of or simulating the Brown-Séquard syndrome, and for the most part offering a favorable prognosis if given the benefit of competent supervision. At this point it should be stated that it is difficult and often impossible to differentiate a hemiplegia per se of spinal origin from that of cerebral origin in an unconscious patient. Accordingly, it is a wise practice in such patients to regard hemiplegia as being of spinal origin until proven otherwise.

Progressive spinal cord involvement may not be appreciated by the patient, especially if his intellect has been clouded by reason of cerebral trauma. The practical significance of this point is that one cannot always be sure that the lesion was immediately complete. Some function may be spared at the time of injury, but later lost as a result of edema and hemorrhage developing during the interval between the accident and the neurological examination. This possibly explains the subsequent recovery in rare cases which had at first received a hopeless prognosis. The possibility of these developments is an argument in favor of decompression of the spinal cord in most cases, regardless of the apparent futility of the procedure.

In those cases presenting definite evidence of cord injury, the level can be diagnosed clinically to within one or two cord segments. However, roentgenograms should include the entire cervical spine, for it is not unusual to find more than one vertebra involved. Open-mouth views are necessary to visualize the atlanto-axial region, and C 7 can be shown by depressing the patient's shoulders. By placing the film casette to the side of and under the neck, satisfactory lateral and antero-posterior views may be obtained without rotating the cervical spine—an extremely important precaution. A common error is to omit the lateral view, which is by far more instructive than the anteroposterior view.

Unless there is marked distortion of the spine, Roentgen findings do not indicate the degree of cord injury. Partial or com-

plete spontaneous reduction is not uncommon. Little or no evidence of dislocation may be found in such patients whose spinal cord was severely damaged at the time of the primary injury. On the other hand, as was demonstrated in one of our cases, there may be over-riding of vertebral bodies without any demonstrable cord injury. This, however, does not detract from the value of Roentgen examination, which is essential for the proper conduct of the case.

After completion of the neurological and Roentgen examinations, which require only a few minutes, treatment should be begun as soon as practicable.

Treatment of patients with fracture dislocations of the cervical spine, accompanied by complete transverse cord lesions, is on the whole most unsatisfactory. The generally accepted view that the cord is instantaneously ruined, holds for most of these cases. Since the cord has no power of regeneration and the permanently paralyzed patient has no need for a good spine, why subject him to useless treatment? The answer is that all writers do not agree that hopeless transverse cord lesions can be diagnosed at once. Accordingly, everything possible to prolong life and to favor return of function should be done in practically all cases. If the patient survives for ten days, he may live for several months or a few years, depending upon the care he receives. Such patients require constant attention for the prevention of bed sores and contractures.

Reduction of the dislocation decompresses the spinal cord by reopening the spinal canal, and provides compensable space for the edematous cord. This not only creates a more favorable condition for return of function, when this is possible, but at the same time relieves nerve root pain, which means much to the patient and facilitates his nursing care. Relief of pain, even for a few hours, more than justifies the employment of effectual traction which can be quickly applied without discomfort, other than that produced by two injections of novocain through a hypodermic needle. (Fig. 1.)

General considerations: The routine care of paralyzed patients has been discussed in many publications dealing with this and related subjects, but its importance has not been generally appreciated, and a repetition of the fundamentals is always in order. There is no group of patients that requires more competent and painstaking nursing care. This phase of treatment must be undertaken at once to prevent pressure necrosis of tissues overlying bony prominences. Attention to this precaution cannot be delayed, for bed sores are prone to take form within the first few hours after injury. These can almost always be prevented if the patient is seen early, and the services of private nurses procured. Air rings placed under the sacrum and heels often do more harm than good. The patient should be placed on an air mattress supported by fracture boards. The sheets must be kept taut, free of loose particles and perfectly dry. The patient must be turned from his back to first one side and then the other at frequent intervals (two hours). As a skin conditioner gentle alcohol rubs followed by powder is recommended. The heels must not be allowed to come in contact with any support. This is easily accomplished by placing a pillow under the calves of the legs. When turned to a lateral position the feet may be suspended by placing a pillow under the lateral aspect of the dependent leg and another between the knees, which also prevents pressure at this point. Anyone familiar with the serious effect of bed sores upon these patients, will at once understand why so much has been said for the cause of prevention. Recovery of cord function is prevented or retarded by a myelitis resulting from infection accompanying these lesions. This is shown by the delay in which tendon and mass reflexes appear in those patients with bed sores, urinary sepsis or infections elsewhere in the body.

Care of the bladder is of equal importance to the prevention of bed sores. Re-

peated catheterization and the use of indwelling catheters, especially in the male patient, lead to severe urinary sepsis, a serious and often fatal complication which for the most part can be prevented by suprapubic drainage. This procedure is advised for all male patients with complete transverse cord lesions at C 5 or lower. Above this level death usually intervenes within twenty-four hours.

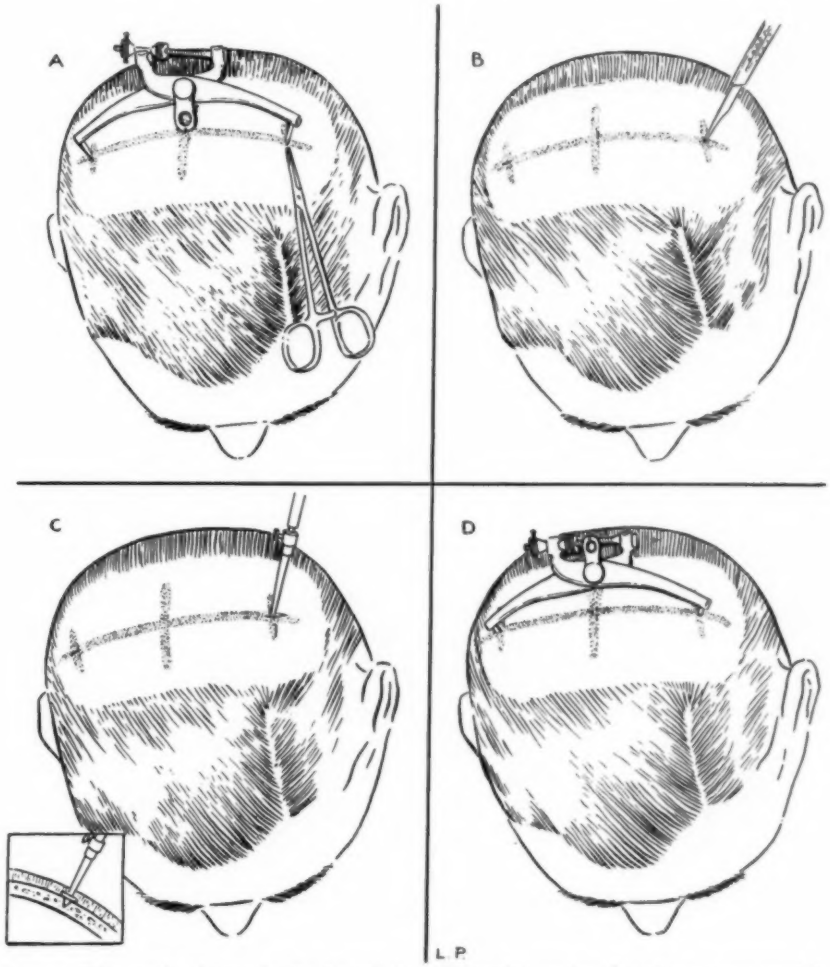

FIG. 1. The author's method of applying skeletal traction for the treatment of fracture-dislocations of the cervical spine. A, for correct placement of the skull tongs, lines are painted on the scalp to indicate the midline of the skull and the approximate plane of the cervical articulations (above mastoid tips). With the traction bar resting on the midline, the tong points are brought down upon the transverse line. These points of contact are marked for the placement of stab wounds. B, after injecting novocaine (1 per cent), stab wounds just large enough to admit the drill guard (inset C) are made down to the skull. C, the drill point is forced to a depth of 3 mm. in children and 4 mm. in adults. The fixed guard prevents excessive penetration. D, the tong points are fitted into the bone perforations and held in position until the tongs have been locked. The tongs should be tightened every two or three days.

Automatic bladder function may be expected within about two months. This is recognized by the intermittent expulsion of urine through the urethra. At this stage the tube should be removed from the bladder and the wound allowed to heal.

Suprapubic cystostomy is also advised for those patients with bladder paralysis resulting from severe but incomplete cord lesions. When the cord is only slightly

injured this operation is rarely necessary, for early return of bladder function may be expected.

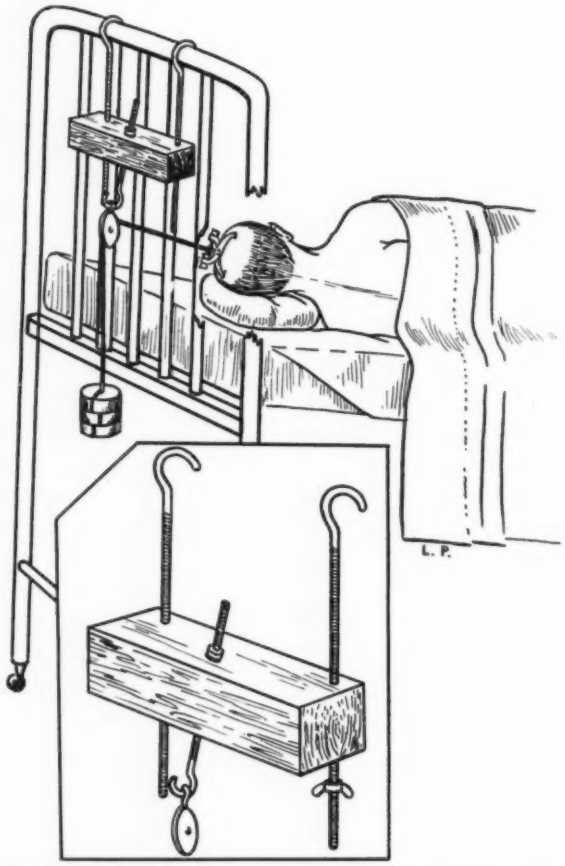

FIG. 2. The patient may be turned to either side while being treated. The same horizontal pull should be maintained to avoid lateral angulation of the cervical spine. A force of 15 to 20 pounds is usually sufficient. We have not used more than 25 pounds. The head of the bed is elevated at least 12 inches, so that the patient's weight will provide countertraction. The inset shows a simple but useful pulley carriage which permits of all necessary adjustments. The pulley hook is set at an angle to hold the sash cord and weights from the bed.

Abdominal distention is at times very distressing, particularly because of its effect upon respiratory function. With paralysis of the thoracic muscles, breathing is carried on mainly by action of the diaphragm which may be impeded by distention of the intestines. By using the rectal tube and enemas this condition may be relieved. Semmes uses for the obstinate and distressing cases, the intravenous administration of 25 per cent sodium chloride (50–100 cc. given slowly).

Fixation of the spine after reduction in completely paralyzed patients is not a major problem, inasmuch as most of them spend the remainder of their lives in bed. A heavy plaster collar adds to their discomfort, and if brought down over the anesthetized skin, it is liable to produce pressure sores. If the articulating facets are not badly injured, fixation is not always necessary. When a recurrence of the dislocation is probable, light traction (about 4 pounds) or a snugly fitting Thomas collar, is advisable until sufficient healing takes place to maintain the reduction.

The care of patients with seemingly hopeless lesions has been stressed for two reasons. First, to give them the benefit of any possible return of function from incomplete lesions erroneously diagnosed as complete, and secondly, for the sake of economy. Particularly when the lesion is low in the cervical region it is possible for life to be spared for a few years. The financial burden is at best very great, and considerably increased when complications such as bed sores or urinary sepsis develop. When these complications can be avoided, it is often possible for the patient to be returned to his home within two or three weeks, where treatment may be continued by members of the family or an attendant at little expense.

Treatment of fracture dislocations associated with partial or no spinal cord injury is very encouraging. This is the more important group, both from the viewpoint of diagnosis and treatment. When cord function is preserved even to a slight degree, useful, and in many cases, almost normal motor power returns. Competent supervision of these cases is imperative to prevent augmentation of cord injury, to relieve cord and nerve root compression and to prevent contractures. Reduction of the dislocation fulfills the first two requirements and in addition leaves the patient with a more mobile spine. Splints are useful to prevent foot-drop. Massage and physiotherapy are indispensable to aid in the prevention of contractures and stiff joints.

The general care of paralyzed patients, which has been discussed, is applicable to patients with severe but incomplete cord lesions.

In those patients with little or no cord injury, pain at the site of injury, limitation of motion and pain radiating into the shoulders and arms are the predominating symptoms. Reduction and immobilization form the ideal treatment, and this requires only a few days' hospitalization, unless there has been marked destruction of the weight-bearing structures.

The idea of skeletal traction for the treatment of fracture dislocations of the cervical spine was conceived by Dr. C. C. Coleman and first used in the treatment of one of his patients in this clinic in 1932. Originally this method was reserved for those cases, which by reason of severe associated injuries of the mandible, were unsuited for other methods of reduction. However, the value of skeletal traction for the routine treatment of fracture dislocations was soon demonstrated. Results have proven that regardless of the cervical level, practically all acute dislocations, and many of those of several weeks' standing, may be reduced without difficulty. The time required to decompress the cord by skeletal traction may be less than that necessary to perform a laminectomy. Cone and Turner, treating a patient with a dislocation of C 5 on C 6, made roentgenograms every ten minutes, demonstrating a complete reduction in fifty minutes by using 25 lbs. of traction.

The high percentage of reductions obtainable, the controllable force and comparative comfort afforded by skeletal traction, make this, we believe, the method of choice for the treatment of these severe injuries.

The Walton and Taylor methods of manual reduction are known to all interested in this field of work. Except in the hands of operators skilled in the conduct of these procedures, it is the opinion of the writer that manual reduction may endanger the spinal cord.

The writer has had no experience with Stookey's method of air cushion reduction in the cervical region. Stookey uses this method for incomplete fracture dislocations. "In the cervical region the principle involved is gradual and continuous overstretching of the neck musculature with the head dependent and the neck in hyperextension."

The method we use for applying skeletal traction and the results obtained have been described in previous publications. The technique used by McKenzie, Hoen, Cone and Turner is somewhat different, but their results are excellent. We prefer to use the small skull tongs* because they are easily and quickly applied, and do not prevent the patient from being turned to either side while in the horizontal position.

Post-reduction immobilization must be individualized according to the degree of cord injury and bone destruction. For ambulatory cases and those with mild cord injuries, hyperextension in a plaster jacket extending from the chin and occiput to the hips, is recommended. This can be discarded usually within three months. A brace or Thomas collar may then be necessary for an additional two or three months, depending upon callus formation and other individual factors.

During convalescence the patient should be observed for evidence of a recurring deformity; atlanto-axial dislocations particularly, which are liable to recur because of injury to the odontoid process. In view of the region involved, life may be seriously threatened. Recurrence at any level is undesirable, but a moderate, nonprogressive recurring deformity giving rise to no neurological symptoms, has not in our experience been sufficient reason for advising an operation for spinal fusion. For treatment of these complications the reader is referred to papers by Kahn and Yglesias and Cone and Turner.

Fortunately, laminectomy is rarely necessary in injuries of the cervical region. It

*Made by George P. Pilling & Son Co., Philadelphia, Pa.

is an operation of considerable magnitude for acutely ill patients, it weakens the spine and does not remove pressure from the spinal nerve roots caught between the displaced bone fragments. As stated by Coleman, laminectomy should be reserved for those cases with a positive Queckenstedt test and showing signs of progressive loss of function, in which there has been a spontaneous reduction or if a dislocation is demonstrable which cannot be reduced by skeletal traction within twelve hours.

SUMMARY

1. A great number of spinal injuries is found in the cervical region, where the most vital part of the spinal cord is either affected or seriously threatened. The necessity, therefore, for prompt recognition and competent supervision of these injuries is urgent.

2. Fracture dislocations of the cervical spine are often associated with severe cerebral trauma, which not only adds to the gravity of the patient's general condition, but makes recognition of the spinal injury more difficult. Unconsciousness, therefore, is a serious handicap and may be responsible for augmentation of spinal cord injury in many cases.

3. The immediate and post-reduction management of patients with cervical cord injury of varying degree, has been discussed.

4. Skeletal traction has been discussed somewhat in detail, inasmuch as we are of the opinion that this is the method of choice for the reduction of fracture dislocations of the cervical spine.

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FRACTURES OF THE DORSAL AND LUMBAR VERTEBRAE

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GENERAL CONSIDERATIONS

FRACTURE of the vertebral column is common, comprising over 6 per cent of all fractures throughout the skeleton. Its importance is not confirmed to its effect upon bony structure and function, but includes the serious possibility of damage to the spinal cord contained within the column. Traumatic lesions of the cord are irreparable, and when at all extensive, are grave tragedies. Cord injury probably occurs not more often than once in ten fracture-dislocations.

In dealing with vertebral body injuries we must keep constantly in mind that the bodies are weight bearing structures, the permanent deformity of which will seriously alter the statics of the column by changing the spinal curves. Thus altered, the abnormal curves subject ligaments and muscles to disabling strain. Failure to completely correct vertebral body deformity is responsible for more of the poor results so commonly seen than all other factors combined. It results in prolonged disability. The correction of the vertebral body deformity (reduction) has during the past few years been perfected to such a degree that the traumatic surgeon may deal with this injury confident of success, provided he carries out thoroughly each step in the treatment.

CLASSIFICATION

These injuries, because of major differences in importance, in etiology, and in treatment are classified as follows:

I. Fracture of the vertebral body, commonly accompanied by fracture of the posterior processes or laminae.

II. Dislocation of the vertebral body, commonly accompanied by fracture of the body and of the posterior processes or laminae.

III. Isolated fracture of the following structures: the transverse, spinous, and articular processes, the laminae, and the pedicles.

PATHOLOGY

The fractures in groups I and II result from violent hyperflexion and lengthwise compression of the vertebral column. The direction of the flexion may be forward, lateral or both. The body of the vertebra is commonly crushed into a wedge-shaped deformity; less commonly the deformity is saucer-shaped due to compression driving the nucleus pulposus above into the core of the body. In most instances (85 per cent) the intervertebral disk is ruptured, so that it never again functions as an hydraulic cushion between the affected vertebrae. One or more of the posterior bony processes are usually fractured when the body crushes, although this is not always demonstrable by *x*-ray. The inter-spinal, flaval and articular ligaments are commonly more or less torn.

If after fracturing the vertebral body the flexion force is not spent, dislocation of the vertebra above occurs (Group II). Dislocation is possible only after tearing of the ligaments both behind and about the vertebral body. The anterior longitudinal ligament which remains intact in fracture is probably always torn, to some degree (at times completely) in dislocation. This must be very clearly understood because the surgeon depends for the safety of the patient's cord during reduction of fracture upon the action of this ligament. He must never rely upon it in reducing dislocation.

The cord may be damaged either through elongation or as a result of narrowing of the lumen of the canal by bone displacement, hemorrhage, or both. The evidence is that cord injury almost always results from

dislocation and almost never from centrum fracture alone. This is often not apparent, since cord injury is common where fracture without dislocation is the *x*-ray diagnosis. I believe that such cases were momentarily dislocations as well as fracture and that the inherent recoil of the column imparted by its twenty-three intervertebral discs caused reduction of the dislocation. This point is significant, for, if it is true, all cord injury cases should be reduced with dislocation precautions to guard the cord against further damage.

Changes in structure resulting from fracture may go on in the column for years. These are found in all cases. They are maximum when treatment has been inadequate, minimum when treatment has been carried out correctly. They include the changes occurring in the column as a whole and in the joints of the lower extremities as a result of the fracture, and those occurring locally. Among the former is the alteration in the antero-posterior spinal curves and the presence of some lateral curvature. These result from the residual angulation at the site of fracture. They set up abnormal stresses and strains which in turn produce, clinically, ligament and muscle strain symptoms. In time proliferative bone changes occur at the attachments of the ligaments to the bone. They are more apt to occur in the lower than in the upper half of the column and tend to stiffen the back. These changes far outweigh, in clinical importance, the local changes, yet receive little or no attention from the average surgeon. Their avoidance by the best obtainable reduction is essential to efficient work in this field.

The local changes include: (1) replacement fibrosis of the damaged intervertebral disc or discs with subsequent narrowing of the involving intervertebral space under the influence of weight bearing: (2) proliferative bone changes at the margins of the end surfaces of the bodies, and increased bone density at the end surfaces; (3) calcification of the ligaments which may result in complete or incomplete bone bridging across what was formerly the intervertebral space; (4) prolapse of the nucleus pulposus which may occur into the centrum, when the herniated portion will become surrounded by a wall of bone, denser than the spongiosa, which can easily be identified in well taken radiographs; or some of the disc elements may become extruded posteriorly and give rise to nerve root symptoms—a very uncommon finding; (5) cord or nerve root pressure may arise from excessive callus which has developed where fragments are not well alined at the time of reduction, or when post-reduction fixation is inadequate.

With alteration of structure there will ensue change of function in the form or loss of adaptibility to the changing stresses of daily life, lowered resistance to wear and tear, and in many cases loss of motion between involved vertebrae. These changes vary in time of appearance and in extent with age, occupation, the previous condition of the column, the extent of the damage and the efficiency of the treatment.

The following tabulation, taken from a series of thirty-one cases of vertebral body fracture occurring in a large community of diversified industry, describes the occurrence of these late local changes.*

	Per Cent
Narrowing of intervertebral space	85
Spurring (proliferative bone changes). (These appeared as early as five weeks and as late as four and a half years)	60
Calcification of ligaments resulting in complete bone bridging	40
Prolapse into the centrum of the nucleus pulposus	30

In group III the fractures are caused either by direct violence or by muscle action. They may be single or multiple, and are, commonly, not as serious as those of groups I and II.

FRACTURE AND DISLOCATION OF THE DORSAL AND LUMBAR VERTEBRAL BODIES (WITHOUT CORD INJURY)

Symptoms and Diagnosis. Early accurate diagnosis is essential to correct treat-

* Rogers, W. A. *Arch. Surg.* 30: 284–324, 1935.

ment. Great violence is not necessary to produce the fracture. The usual history is of one of the following accidents:

1. A fall, the patient having landed upon the feet or buttocks, or upon the head, neck or shoulders.

2. An automobile accident, the patient having been flung against the car or the ground.

3. A dive into shallow water, the patient having struck the back of the head or neck upon the bottom.

4. A blow, a heavy object falling upon the head, neck or shoulders when the spine is flexed.

Such accidents so frequently result in this injury that the burden of proof rests with the surgeon that fracture is not present when a history of one of the four is given.

Pain may be localized to the region of the spinous processes about the fracture and "deep in" at the level of the fracture with or without a sense of girdle constriction, or it may be diffused over a considerable part of the back. Pain may be referred along part or all of the corresponding peripheral nerve segments. There will be more or less surgical shock. Muscle spasm in the back and abdomen is usually marked. The angulation of the vertebral column at the site of fracture is much less apparent than the radiographs indicate. Local tenderness and thickening at the spinous processes about the fracture are common early findings. Motions should not be tested.

When the cord is injured, there is paralysis, both motor and sensory, below the level of the lesion. This may be partial or complete. When paralysis is complete the muscles are flaccid and the tendon reflexes absent. Later, if the cord lesion is partial, this may change to spasticity with increased reflexes. There may be temporary suppression of urine. Retention of urine and feces exists, followed by incontinence. The urinary tract may become infected which may ultimately lead to death from renal impairment. A narrow girdle of hyperesthesia may exist immediately above the upper limit of anesthesia. Vasomotor failure with elevated surface temperature may occur and with it priapism, if the lesion is above the first lumbar vertebra. Bed sores may occur in spite of the best nursing care, and the skin upon dependent parts may slough. When paralysis is partial the Brown-Sequard syndrome may be found but usually the character and degree of the motor and sensory change is very irregular. Bladder and rectal control may not be completely lost.

In nerve root injuries, disturbances in sensation and flaccid paralysis may be found in the distribution of the corresponding peripheral nerve, with or without lancinating and neuralgic pain.

X-ray: Accurate diagnosis is possible only through radiographs which reveal the best obtainable bone detail. These must be taken in both the antero-posterior and lateral planes and, when safe, should include the entire dorsal and lumbar region, since scattered fractures may be present and one or more of them may be silent. The radiographic study should also include the lumbosacral junction for local factors predisposing to strain, since this region suffers most from faulty spinal mechanics, altered through deformity incident to fracture of the vertebral body.

Complicating injuries can easily be overlooked. Not uncommonly the os calcis, the pelvis, the sacroiliac joints, the transverse processes, the ribs and sternum are also fractured.

Treatment. Emergency: When fracture or dislocation are suspected the patient should be very carefully rolled, where found, onto a rigid stretcher, door blind, planking, etc., which has been padded with blankets or other such material. In rolling, great care should be exercised to avoid twisting or flexing the body. These cases should never be sat up. They must be placed face down upon the rigid carrier and be transported in this position. The arms are folded under the head. If there is paralysis, all hard objects should be removed from the clothing such as buttons, tools,

etc. since these may start pressure sores in paralyzed areas. Transportation, preferably to a well equipped hospital, should be as quick as possible.

Prereduction Care. If shock is present, morphia, warmth, and intravenous saline-glucose should be administered immediately. When paralysis has occurred, the protection of the affected parts must be kept in mind from the start. Otherwise, pressure sores will develop, or sloughs occur at dependent portions. As quickly as justified the *x*-rays are taken. If the *x*-ray technicians are not well trained in the moving of these patients into the standard positions, the surgeon should be present to direct.

The injured should be placed in a supine position in a bed equipped with boards between the springs and mattress, or else upon a frame of the Bradford type. Narcotics are indicated for pain and the abdominal distention so frequently present following these injuries. Catheterization is usually unnecessary since bladder control is soon re-established when the cord is not injured. If the return of bladder control is delayed, enemata as a rule suffice to hasten its restoration as well as to aid in combating ileus. The time selected for reduction varies.

Reduction. Time of reduction: If symptoms of cord injury are present, reduction of fracture and of dislocation should be carried out at once unless marked shock makes delay necessary. If dislocation is present without symptoms of cord injury, reduction should likewise be attempted at the earliest possible moment since there is always danger of cord damage in this group until reduction is complete. When shock has cleared up and muscle spasm subsided, usually in a day or two, reduction in the fracture group may be effected.

Technique of reduction: The keynote of successful reduction is complete hyperextension of the vertebral column. By this means the compressed fragments of the crushed body are drawn into normal relationship by the pull of the longitudinal ligament. The torn ends of the posterior ligaments are approximated. Anything short of complete hyperextension will fail to effect reduction. It is the last few degrees of hyperextension which actually produce reduction.

Anesthesia: A general anesthetic should not be used. It is dangerous and unnecessary. Morphia and scopolamin by hypodermics will produce sufficient muscle relaxation and allay apprehension. The dosage varies with the patient's age and weight. For an average adult, morphia grs. $\frac{1}{6}$ and scopolamin grs. $\frac{1}{200}$ in two doses, one hour apart, should be satisfactory.

Methods of Reduction. There are a number of efficient methods of producing spinal hyperextension. Only those should be employed which are under absolute control, do not require an anesthetic and are convenient. Among these are the suspension,[1] the flexible frame,[2] the sling-traction,[3] the Abbott frame, the Goldthwaite Irons, and the table methods.[4] The following techniques represent a modification of several of these. Each fulfills the requirements of a sound method, is very simple, and the apparatus is within reach of all traumatic surgeons.

Choice of method: The problem of reduction in the lumbar region is very much easier than in the dorsal. A fracture three days old in any region can be more easily corrected than one unreduced for a week or longer. Fractures involving the posterior wall of the centrum require powerful traction during extension so that the posterior fragments will not be pushed backward against the cord or nerve roots during reduction. The reduction of vertebral dislocation is always dangerous and requires a special and sometimes elaborate technique. Therefore, each fracture should

[1] Davis, A. G. *J. Bone & Joint Surg.*, 11: 133 (January) 1929.

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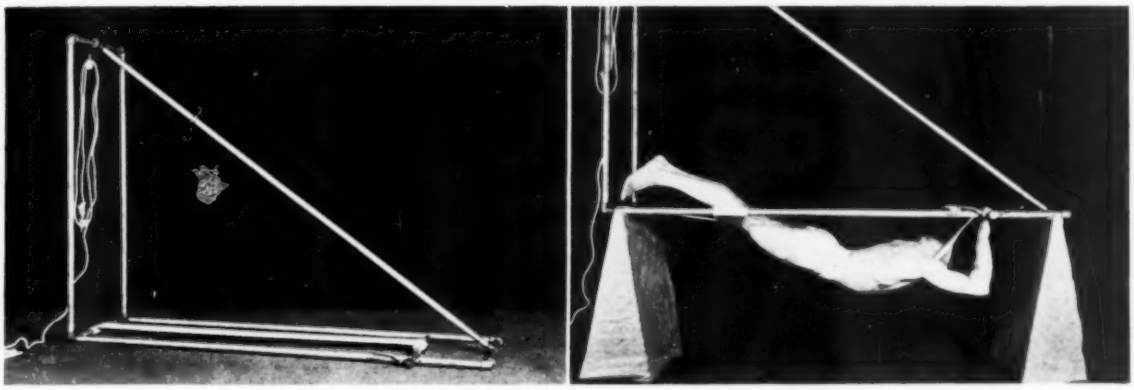
[3] Dunlop, J. and Parker, C. H. *J. Bone & Joint Surg.*, 15: 153 (January) 1933.

[4] Jones, R. W. *Brit. M. J.*, 1: 300 (Feb. 2) 1931.

be carefully analyzed with these points in mind and the method selected so as to meet the requirements of the individual case.



A B

FIG. 1. A, a convenient type of hammock frame. The canvas hammock is operated by means of a ratchet and pawl so that it is always under the complete control of the surgeon. B, the patient has been placed face downward upon the hammock, which has been allowed to sag gradually until the patient's spine is in complete hyperextension. The felt padding may now be arranged about the torso and the jacket applied.

SIMPLE CRUSH FRACTURE, LUMBAR OR ELEVENTH, TWELFTH DORSAL VERTEBRAL BODY

No dislocation is present, the posterior wall of the body not involved, the fracture less than a week old. (Fig. 1.)

Hammock Method. The patient is placed prone upon a flat canvas hammock eight inches wide which has been stretched lengthwise on an ordinary Bradford frame, and which is permitted to sag downward, slowly, until complete spinal hyperextension has been obtained. The sagging of the hammock may be controlled by hand or by a rachet device at one end of the frame, as may be seen in Figure 1. (The same effect may be produced by using a sheet folded lengthwise until about 8 inches wide. Each end is securely fastened to a table so as to be taut when the tables are separated about the length of the patient's torso. Upon the hammock and tables the patient is placed, face downward, the head and arms on the end of one table, the lower extremities upon the other. The torso rests upon the hammock. The head table should be about 1½ feet higher than the other. The hammock is permitted to sag slowly by moving the tables together.) The limit of extension varies with age, build, posture, hypertrophic changes, etc., and there is no rule by which it may be accurately determined. When the patient begins to complain of aching in the lumbosacral region the operator may be sure that he is at or near full hyperextension. By carrying the extension a little beyond this ache point after several minutes at a less degree of extension, the absolute limit becomes reasonably assured.

When complete hyperextension has been obtained, radiographs may be taken with a portable *x*-ray unit to confirm the reduction. The torso is then covered with felt over stockinette, one-half inch being used over the back, one quarter inch along iliac crests and over the anterior chest wall. The plaster jacket is applied and the hammock removed.

The plaster jacket: The plaster-of-Paris jacket (Fig. 2) is applied with the spine in complete hyperextension while the patient is on the hammock. A shirt or stockinette covering should be applied before the patient is placed on the hammock. This will now be ready for use. A piece of one-half inch felt is used to cover the back from the lower angles of the scapulae to mid-sacrum. A one quarter inch band of felt encircles the pelvis and another the upper chest to protect the iliac crests, and ribs and sternum, respectively. Over these are applied the

plaster of Paris bandages until the jacket is about one quarter inch thick. The plaster is then allowed to dry and is trimmed so

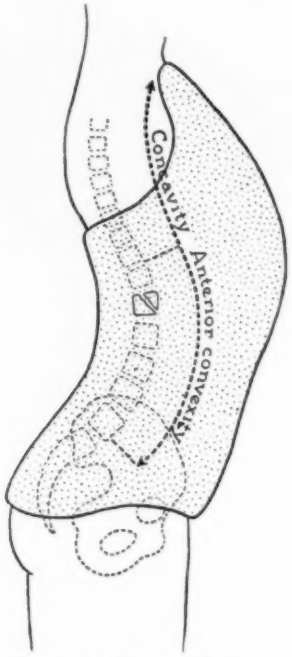


Fig. 2. Diagram showing extent of plaster jacket used in the treatment of lower dorsal and lumbar vertebral fractures. (From Christopher's Textbook of Surgery, W. B. Saunders Company, 1937.)

that, in front, it extends from the suprasternal notch to just below the anterior superior spines; behind, from the lower angles of the scapulae to mid-sternum. The hammock is cut and withdrawn.

After Care. The jacket should be worn for about four months, during which time the patient's weight should be watched, since any considerable loss renders the jacket inadequate. In the cases in which the centrum is severely crushed, it is well to continue the use of the jacket for another month or more. The patient with a jacket may be ambulatory provided the weight above the fracture falls on the intact posterior portion of the centrum. In other words, if the fracture lies in the anteriorly convex portion of the curve of the vertebral column, the weight will be carried on the posterior wall of the centrum, and the patient should be ambulatory. If, however, this requirement is not satisfied or there is lateral crushing or the patient is very obese, the same treatment should be carried on but with the patient recumbent. Plaster-of-Paris shells may occasionally be necessary. After the period of jacket-fixation, a high back brace is worn for about a month, during which exercises are vigorously pushed.

Exercises. Active spinal extension and abdominal retraction should be started within a few days of reduction and kept up throughout treatment. As fixation is being gradually withdrawn, lumbar flexion and pelvic rotation must be insisted on so as to obliterate the deep lordosis resulting from the hyperextension necessary to correction and fixation. Otherwise backache will ensue. By means of these exercises the ideal of treatment is achieved whereby a normal range of motion and muscle strength are gained by the time the bone union is complete. In this way the patient is spared long periods of rehabilitation and discouragement.

FRACTURE, LUMBAR OR ELEVENTH, TWELFTH DORSAL VERTEBRAL BODY

The fracture involves the posterior wall of the body (also all simple crush fractures over a week old).

The Suspension Method (Davis). The patient, relaxed by morphine-scopolamine, and with the trunk covered with stockinette, is placed face down upon the taut canvas as in the hammock method. The ankles are heavily padded with sheet wadding and ankle slings applied over this. A pulley block and tackle is fastened to the ankle slings, preferably by a spreader. The other pulley block is fixed to a point about 12 inches distal to the feet and high above the frame or table. The lower extremities are gradually raised by means of the block and tackle while the patient retains position on the hammock by firmly grasping the frame or table. (See Fig. 3.) This

maneuver is carried out slowly, especially at the start to overcome muscle spasm and with frequent pauses during which cord function may be checked by having the patient move the toes. Impending cord pressure during reduction is heralded by motor weakness, nerve root pressure by shooting pains in the lower extremities. Both are preceded by severe pain at the site of fracture. Since general anesthetic is not used, injury to the cord during reduction can, therefore, be readily avoided. The limit of hyperextension is reached when the pelvis and lower abdomen have been raised several inches above the canvas sling, the thighs make with it an angle of about forty-five degrees and lumbosacral backache becomes persistent. The reduction requires but a few minutes. Radiographs may then be taken while the patient is still suspended to confirm the reduction. When hyperextension has been carried to the physiologic limit, the fracture or dislocation is commonly fully reduced and the angulation can no longer be seen or felt. Occasionally, however, this may not be the case. The period of suspension should then be prolonged to overcome muscle spasm, and gentle manipulation of the trunk from side to side while the patient is still suspended or gentle downward pressure by the surgeon's hands may be necessary to free locked articular processes or disengage impacted fragments. Reduction having been effected, the traction cord is made to give slightly and at the same time the hammock is loosened until the ventral surface of the entire trunk rests upon the hammock. The felt pieces are then applied, one about the chest, one about the iliac crests, and the third—the thicker—along the spinal column from just above the angles of the scapulae to the mid-sacrum. A plaster jacket is then applied with the patient in suspension. As quickly as this has dried, the traction is released, the canvas hammock cut and withdrawn and the patient returned to bed. In cord injury cases with trophic disturbance the jacket should be immediately bivalved to permit care of the skin, and Cabot or other similar splints should be applied to the well padded lower extremities.

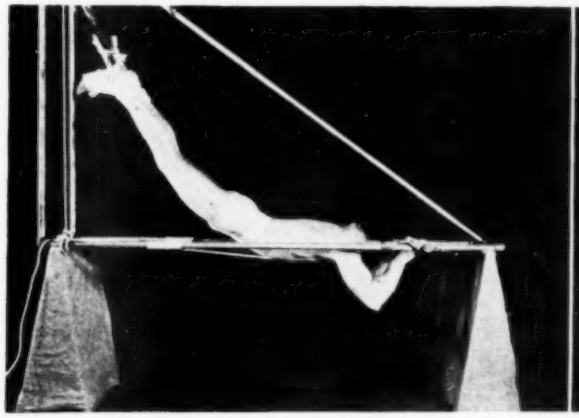


Fig. 3. The suspension method of obtaining spinal hyperextension combined with traction. The patient is placed face downward upon the hammock. The lower extremities are gradually raised by means of the block and tackle. The surgeon is thus able to extend the spine gradually while the correcting forces are always under complete control. The felt padding may now be arranged about the torso and the jacket applied.

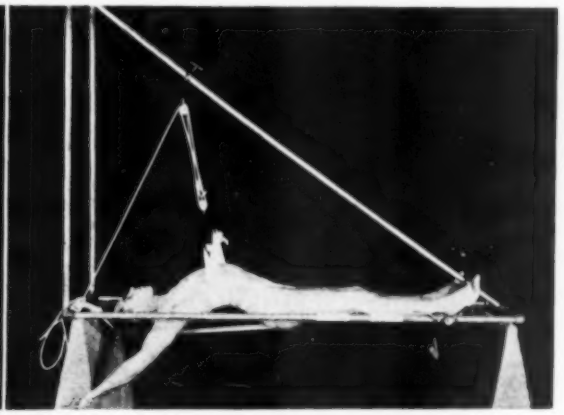


Fig. 4. The hammock frame adapted to the sling method of obtaining dorsal hyperextension. Reduction is very much more difficult in the upper ten dorsal vertebrae and greater forces are necessary. The same mechanism may be employed with tables, as described in the text.

DORSAL VERTEBRAE (ABOVE ELEVENTH)

Sling Method (Dunlop). The patient, prepared for reduction with morphine-scopolamine and covered with stockinette from the head to the upper thighs, is placed supine upon a small table or on the ham-

mock frame (Fig. 4) with the occiput resting upon a table or instrument stand adjoining. The lower extremities rest upon

Fig. 5. Jacket employed in fracture involving the upper ten dorsal vertebrae. Because of the anterior concavity of the spine in this region, it is necessary to support the entire superincumbent weight by the jacket. To this end, the neck, chin and occiput must be included.

a third table or stand. A canvas sling, six inches wide, is passed under the chest beneath those segments of the thoracic spine immediately below the level of fracture. The sling is fixed to a spreader, block, and tackle, and by means of the latter is slowly raised until the column is suspended at a point just distal to the fracture. That portion of the table which is beneath the trunk and buttocks is removed. The elevated arms are held by assistants or by the patient grasping the table at the head. In this way the weight of the body above the fracture imparts extension and traction. It may be necessary for the surgeon to make use of manual traction on the arms or downward pressure upon the upper chest and the shoulders in order to effect reduction.

When reduction has been effected, as disclosed by lateral radiographs, a jacket is applied as in lumbar fracture, but it must, in addition, be made to include the neck, chin, and occiput. The chin, occiput and thyroid cartilage as well as the usual regions of the trunk are protected with felt. The arms are left free. As quickly as the jacket is dry, the sling is cut and removed and the patient returned to bed. The jacket is seen in Figure 5.

After care: Patients should be ambulatory in the jacket in order to preserve muscle tone and morale. The period of fixation is determined as in the lumbar fractures and exercises are started early and are stressed. The jacket may be followed in the lower thoracic fractures by a high backbrace; in the fracture of the upper thoracic vertebrae by a leather Doll collar.

DISLOCATION

Reduction of vertebral dislocation may be very difficult to accomplish and when it is not done with the greatest care may result in cord or nerve root damage.

Reduction may be attempted by the suspension method, described above. If the procedure is done very slowly and without a general anesthetic, the surgeon should be able to detect impending cord or nerve root injury in time to avert irreparable damage. At the first sign of cord or nerve root pressure the extension must be stopped and the spine gently returned to the position present before extension. A jacket should then be applied to safeguard the back until open reduction can be performed.

Failure by extension to reduce many dislocations is due to locking of the posterior articulations. These processes can be freed by open reduction, a procedure which may prove very difficult. It should not be attempted by those not fully equipped and trained in neuro-surgical technique. The operation should be done under local anesthesia. As soon as the facets are freed, the spine should be hyperextended and the jacket applied.

The after-care following reduction is the same as in fracture.

TRANSVERSE PROCESSES

This type of fracture is frequently regarded as a grave injury. This is erroneous. It is in reality a minor one. A firm adhesive-plaster strapping, removed and renewed at five-day intervals for several weeks, is indicated. Rest in bed for one or two weeks is sometimes necessary when several processes are broken. Rarely extensive hematoma necessitate the use of a plaster jacket or shell. Attempts at reposition of fragments are not successful and are unnecessary. When healing is well advanced, usually in two or three weeks, exercises should be started and a belt be worn for a month or two. The period of disability usually lasts for from one to eight weeks.

A common error of considerable medico-legal significance is to diagnose as a fracture (1) accessory rib or (2) anomalous ossification center which has not fused with the remainder of the process. This mistake may be avoided by noting the jagged line in fracture and the smooth, clearly marked line of anomaly.

"The symptoms of nerve injury [in fractures] are tingling, pain, numbness or loss of sensation along the sensory distribution and paralysis in the motor distribution on the involved nerve."

"In case of partial or complete nerve injury [in fractures], the paralyzed muscles should be supported and conservative treatment should be adopted. If some return of frunction is not noted within four weeks, exploration of the nerve should be considered."

FRACTURES OF THE PELVIS

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MODERN high speed transportation is unquestionably responsible for the fact that fractures of the pelvis, at one time considered somewhat of a rarity, are growing relatively common.

In a period of seventeen years extending from July, 1920, to July, 1937, 261 cases of pelvic fracture have been admitted to the Employees' Hospital at Fairfield, Alabama. Two previous papers,[1,2] published by us, set forth a large proportion of these cases and suggested in detail a standardized method of treatment.

The surgeon who occasionally treats pelvic fractures should always bear in mind certain outstanding facts: (1) that pelvic fractures are more often multiple than single; (2) that in a large proportion of these cases there are other serious injuries as well; (3) that the careful study of the patient and his protection against additional shock are far more important than hasty diagnosis and immediate treatment of the fracture; (4) that absolute anatomic reduction is not essential to good functional recovery and that slow reduction accomplished in an almost routine way is applicable to a vast majority of such cases.

Fracture of the pelvis should always be suspected in patients who have suffered from trauma about the midsection of the body, whether in an overturned automobile, in falling from heights, or from any type of crushing injury. Frequently there is little to direct attention to the pelvis beyond generalized pain in the abdomen or about the hips and back. In many instances people so injured have walked for considerable distances after receiving serious pelvic fractures. Positive diagnosis can be made only with the aid of properly taken roentgenograms.

If fracture of the pelvis is suspected, there should always be a careful investigation of the bladder and urethra. In a very large proportion of cases of pelvic fractures blood will show in the urine in greater or less amount. Although in the majority of instances this is only a transitory matter, in a small proportion of cases actual rupture of the bladder, either intraperitoneal or extraperitoneal, occurs. Injuries to the deep urethra in men are also relatively common, while in a very few cases there may be peritoneal nerve injury, probably as a result of trauma to the lumbosacral cord at the pelvic brim. Occasionally marked edema of the extremities persists over a period of several months following fracture of the posterior ring and in the Malgaigne type of fracture. This edema may persist for a very long period and be practically disabling. These occasional complications are sufficiently frequent to make one hesitant in giving an early prognosis in any type of pelvic fracture.

In broad terms, pelvic fractures may be classified in three groups: (1) single fractures in which the continuity of the weight-bearing ring is preserved; (2) multiple displaced fractures in which it is necessary to relieve the bearing of weight until the fractures are consolidated; and (3) the double vertical fractures (Malgaigne's fracture) in which there is usually extensive dislocation of the whole pelvis.

In the anterior ring fractures and marginal fractures best results are obtained. In fractures of the acetabulum fair results may be anticipated, but in the fractures involving the posterior ring about the sacro-iliac joint, the outlook is relatively poor.

TREATMENT

Immediately on admission to hospital the patient should have a painstaking

physical examination, but with a minimum of handling, to determine as quickly as possible the extent of the injuries suffered. If the patient is not in too severe shock, roentgenograms are taken with great care, preferably by means of a bedside unit. However, should the patient be in severe shock, appropriate measures are taken before any attempt at a general examination is made. As soon as fractures of the pelvis are demonstrated, a specimen of urine should be secured, by catheter if necessary. If gross blood shows in the urine, the extent of the bladder injury should be determined with the greatest care but with the least possible trauma to the patient.

Where there has been an intraperitoneal rupture of the bladder, very little, if any, urine will be secured by catheter. Many methods have been suggested by various writers for quick determination in these cases, ranging from the instillation of sterile fluid into the bladder and its withdrawal to decide on leakage, to the injection of an opaque substance followed by roentgenograms. Practically, however, we believe that it is generally best to wait for several hours. If after several hours the catheter shows practically no urine, and if there is additional evidence of peritoneal invasion, the diagnosis is plain and little damage has been done by waiting. In these cases, provided the general condition of the patient permits, laparotomy should be done and intraperitoneal suture of the bladder performed, supplemented, of course, by constant drainage over a period of days.

Extraperitoneal rupture of the bladder is more frequently encountered than the intraperitoneal type. Here leakage from the bladder is usually much less rapid and is accompanied by definite signs of extravasation, also usually by considerably more blood in the catheter specimen than in the extraperitoneal cases. It is then best to explore the bladder extraperitoneally, to suture if possible, or to drain, with supplemental drainage per urethra.

A large proportion of these patients will show evidence of massive hemorrhage about the fractures, evidenced by swelling, discoloration, and frequently by rather marked abdominal symptoms, such as rigidity and pain. Unless there is unquestioned evidence of bladder leakage in such cases, open drainage should not be done, since this simply compounds the fracture but accomplishes little else. If there is undoubted evidence of deep laceration or even division of the deep urethra, evidenced by hemorrhage from the meatus with difficult or impossible passage of a soft catheter, suprapubic drainage of the bladder should be promptly resorted to, to be followed later by appropriate treatment of the urethral lesion. After the determination, and appropriate treatment of complications, a standard treatment is followed out by means of an overhead pelvic suspension frame.

Suspension is obtained by a canvas sling or hammock which extends from the upper third of the thighs to the lower dorsal region. This hammock acts as an immobilizing factor because of the lateral compression action on the pelvic girdle. The suspending force, approximately equal to the body weight, is continually in action, and as relaxation of the muscles takes place, there is a constant tendency for the displaced fragments to fall into their natural position. Generally, within the first few hours following the application of the pelvic hammock, marked relief of pain is noticeable.

The amount of weight on the hammock suspension is regulated by the weight of the body area which the hammock supports. It is the aim to use sufficient weight almost to counterbalance the weight of the patient, but not enough to raise the patient completely from the bed. Weights used for leg traction vary from 4 to 8 pounds, depending on the size of the patient and the type of the fracture. Cases in which there is involvement of the posterior ring or sacroiliac dislocation require more weight. It may be necessary to apply more weight on

one side than the other, depending on the presence of overriding.

Suspension is supplemented in every case by traction on the legs and thighs, with about 15 to 20 degrees of abduction of the thighs at the hips. Abduction relieves the marked spasm of the strong adductors of the thighs and pelvis, prevents scissoring of the thighs, tends to pull the fragments back into place, and prevents the limited abduction that is so commonly observed following these injuries.

Leg traction is used in all types of fracture of the pelvis except in the event of an isolated fracture of the anterior-superior or anterior-inferior spines of the crest of the ilium. In these only the hammock suspension is used, supplemented by flexion of the knees by the use of pillows, at about a 20 to 30 degree angle at the hips.

A wooden spreader is used in certain cases to prevent too great a lateral pressure, since lateral pressure of the hammock may cause an overlapping of the points of fracture unless it is offset by the intelligent use of the spreader. The degree of lateral pressure can easily be governed by the raising or lowering of the spreader, which should be the exact width of the individual's pelvis within the canvas sling. The use of the spreader should be a part of the routine treatment unless a separation of the symphysis is present. In such cases a marked amount of lateral pressure is necessary and is obtained by the use of the hammock without the spreader.

The method of treatment described gives a high degree of ease and comfort to the patient, greatly simplifies nursing care, prevents a certain amount of muscular atrophy, allows for improved circulation throughout the pelvis, and provides easy access for care and dressings when the soft parts have been injured. In the simple, uncomplicated cases, it is rarely necessary to administer an anesthetic in application of the overhead pelvic frame and traction.

We believe that pelvic fractures should be treated in this way by traction and suspension for an average period of at least forty-two days. At the end of this time the hammock is removed and the patient is allowed to move about in bed for another week. A pelvic belt is applied immediately after the removal of the hammock.

At the end of the seventh or eighth week the patient is allowed out of bed and begins weight bearing with the aid of crutches. Gradual increase of weight bearing is determined by the amount of callus formation as shown by *x*-rays and by the comfort of the patient as weight bearing is increased. In certain cases callus formation has definitely been hastened as increased weight bearing is allowed; but this method is resorted to only in carefully selected cases. As convalescence proceeds, daily hot tub baths and local heat are used.

There can be no question as to the value of electrotherapy, hydrotherapy and massage in these cases, and when such supplemental treatment is available it should be freely used.

Patients should be kept under close observation until full return to duty is permitted, since it is most important in securing good results to watch them carefully over a long period. Good judgment must be used in sending these patients back to work. It will be found that if they are forced too much, they are inclined to develop muscular spasm of the back and thighs, which necessitates a return to bed and a consequent lowering of morale. In the series quoted the number of days lost from work averaged approximately 140, if the accompanying injuries were not disabling.

In our experience only about 55 per cent of the total series of patients had what we regard as good anatomic position when discharged, but in spite of this fact the vast majority of patients had excellent functional results. We believe that what appears to be a poor position of the fragments is by no means a constant cause for persistent pain and disability. It has been frequently observed that in cases in which there was marked displacement of fragments there was less pain and less disability

than in others in which excellent position was secured. It is believed that the standardized method of treatment by use of the overhead pelvic suspension frame, with traction on the lower extremities, will yield excellent results in a higher proportion of cases than any other method.

SUMMARY

Pelvic fractures should always be suspected in patients who have been involved in high speed accidents when pain is complained of in the midsection of the body.

The vast majority of pelvic fractures are simple to treat and brilliant results are obtainable if the simple routine outlined above is followed.

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"When a bone is broken, the ends of the bone do not heal in the strict sense of the word; that is, there is no tendency for actual growth to take place from the end of a bone fragment, but under favorable conditions the continuity of the bone becomes reestablished by the soldering together of the ends of the fragments by new tissue which is laid down around and between them."

NON-OPERATIVE TREATMENT FOR FRACTURE OF THE NECK OF THE FEMUR

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INTRACAPSULAR fracture of the neck of the femur presents a challenge to the profession. The fact that it is a fracture largely of the decades between sixty and eighty when life is not so vigorous, and since the statistics of past years show that the end-results of treatment of this fracture have fallen far short of the desirable goal in obtaining bony union and reasonable functional results, and that the mortality rate is higher than should be expected in an injury intelligently treated, and that there is still among the general profession a more or less fatalistic attitude toward such fractures with a feeling that it is hopeless to attempt or to expect satisfactory results in the aged, amplifies that challenge.

One who has studied the numerous articles read and published during the past eight or ten years realizes that improvement has travelled a long road and that today all accepted methods reported have increased the percentage of good end-results. These results are now established as ranging from 65 per cent to 85 per cent. For the past six years arguments have been presented for and against many methods of solving the problem. At this particular time those who favor internal fixation by nails, wires, pins and lag screws constitute a majority. Conservatism, however, will always be the port of solace whenever storms of trouble arise. This article will not argue the merits of conservatism versus internal fixation, but will present the most efficient and conservative procedure, knowing that all who read will have an open mind for the more highly technical methods which either through lack of special training or dearth of special equipment cannot be used efficiently by all practitioners who are called upon to treat these injuries. The object of treatment is to obtain good union or a functional union without loss of life.

In all fracture treatment three steps must be carried out; first, anatomical reduction; second, adequate fixation and, third, preservation of physical health. The last especially applies to fractures of the neck of the femur.

REDUCTION

Due to anatomical peculiarities, absolute reduction must be obtained in these fractures. Since dependency for union is placed on the cancellous structure and since circulation is at best a questionable quantity, the only hope of union lies in anatomical reduction. It is a fact that there is a long lever arm, the distal fragment, which includes the distal portion of the neck and the entire shaft of the femur, and a short lever arm, the head and medial portion of the neck of the femur. The neck makes an angle of approximately 125–130 degrees with the shaft. This is important to remember when the amount of abduction after reduction is to be determined. A capsular ligament surrounds the entire neck and its fibres are in a state of torsion due to the rotation of the neck in early infancy. In other words, the evolution of the hip joint to an erect walking position is that of a change from the quadrupedal position of infancy to the erect position of human gait. The muscular structures about the hip are so arranged that the center of rotation lies in the axis of the neck of the femur with the result that in a position of 90 degrees flexion of the hip, all of the muscles controlling the joint are fully relaxed. This anatomical arrangement lays the foundation for the genesis of the following method of reduc-

tion which can be accomplished readily and easily.

The injured leg is flexed at the hip to 90 degrees with the leg at 90 degrees to the thigh. Manual traction is applied in the axis of the flexed thigh together with slight adduction of the femoral shaft. In this position the thigh is internally rotated and the leg is slowly circumducted into abduction, the internally rotated position being maintained. As the leg is brought down to the table level, the heel-palm test should be applied to confirm position. After the leg has been brought down in the estimated degree of abduction and internal rotation, the heel of the injured leg is allowed to rest on the outstretched palm. If the reduction is complete, the leg will not evert itself. Should there be no interlocking of the fragments, however, the leg will slowly rotate externally. This has been found to be an invariable test. In all cases where the test evidenced internal rotation, the reduction was anatomically complete. In cases where the internal rotation had to be forced, the reduction was never complete, as proven by anterior-posterior and lateral *x*-rays, the only criterion for a good reduction. The observation is made that as the leg is circumducted into a position of abduction and internal rotation without tension, the position of the leg tends to assume the proper degree of abduction and internal rotation.

The amount of measured abduction is determined by inspection of the *x*-rays taken previous to the manipulation, comparing the angle of the uninjured side with that of the fractured side. The difference of the two angles in degrees is roughly the amount of abduction required. It can be still more accurately determined and verified by applying the heel-palm test which allows only a few degrees of variation in abduction or adduction before change in the position of the leg takes place. For example, if the leg is carried too far toward the adduction side, it will slowly evert itself in the palm of the hand and give evidence of disengagement of the fragments. If abduction is forced beyond the normal limits necessary to maintain coaptation of the fragments, then greatly increased tension of the adductor muscles will be felt and there will be a tendency for the knee to flex slightly. The definite tension of the adductors and the slight flexion of the knee can be neutralized by allowing the leg to assume a small angle of abduction. This has been found to be a very satisfactory method of determining the amount of required abduction in a given reduced fracture. The leg is then held by an assistant without traction and the plaster applied in accordance with the following technique.

Fig. 1. Typical position of leg before reduction.

FIXATION

Reduction having been obtained and checked by the heel-palm test, the next step is that of plaster application, which may be done either with the single hip spica or with the double hip spica. The author uses the single hip spica which is applied in the following manner. A one-layer thickness of glazed cotton is placed about the torso from the nipple line over the affected hip to a point about half-way between the hip and the knee. Then a long strip of felt, one-half inch thick, is placed about the pelvis, extending from just above the iliac crests to the trochanters, and completely encircling the pelvis. This is all the padding necessary and allows very tight application of plaster. The body portion is first applied as tightly as possible, snug coaptation being the aim. Firm pressure over the injured hip is necessary. Below the hip no padding is applied. Two plaster slabs molded carefully to the contour of the leg, one posteriorly and one anteriorly, are bandaged closely to the skin. Padding is placed beneath the heel only and the plaster molded well. Circular plaster is applied around the two molded leg splints. Care is then taken to carry the cast high under the pubis and the ischium with sufficient felt padding to prevent discomfort. The U is then cut from the body segment of the cast anteriorly, leaving the sides high in order to prevent the patient from swinging to the opposite side, thereby changing the relative position of body and leg. Extreme abduction is rarely necessary.

FIG. 2. Flexion to 90 degrees. Traction in axis of femur.

FIG. 3. Adduction. Traction maintained.

Change of plaster may be indicated in stout individuals. We all experience the problem of the loose cast in such patients three to four weeks after application. Fixation is less secure, although the skin coapted plaster diminishes the chance of slipping. The necessity for change may be determined by frequent inspection of the cast. *X*-rays immediately after and at intervals of two weeks show change of position of the fragments. If mal-position is noted without absorption of the neck, reduction should again be done and the case treated as before.

AFTER-CARE

Whatever method of reduction and fixation is selected, the writer believes that the so-called after-care is the most important in the preservation of life. It is a good rule to know your patient. Before treatment is instituted a thorough physical examination should be done since good results depend largely on the patient's own recuperative power and to no small extent on their mental cooperation. The cardio-vascular-renal system should be examined carefully for any organic disease or decom-

pensation. Dehydration in the elderly patient when present should always be recognized and treated before any attempted correction of the injury is made. Intestinal stasis is an important element to be considered, especially in the patient of advanced years. Because of age, the functions of the individual are at a basic level and, in most cases, trauma and subsequent shock have caused the vitality to drop to a still lower level. It is essential, therefore, that no treatment be instituted which will further depress the vital centers. In this connection, opiates, in the opinion of the author, are contra-indicated as they serve only to create a depression from which the individual may not readily rally. Good elimination and frequent change of position are important. Due attention to the two dangerous complications—general toxicosis predicated on dehydration and intestinal stasis, and pulmonary hypostasis—will aid in preventing the third serious complication that of mental bewilderment, delirium or psychosis which is a danger signal.

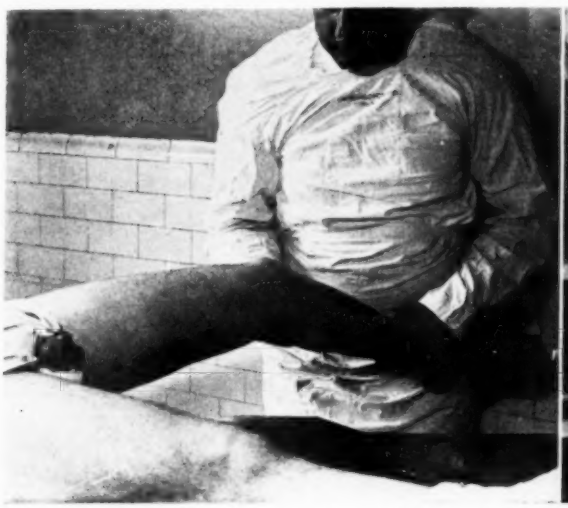

Fig. 4. Circumduction to estimated abduction.

Fig. 5. Heel-palm test. Note maintenance of internal rotation.

Except for those cases in the most dire physical condition, one should not shrink from applying plaster. To treat these fractures of the later decades of life by sandbags, Buck's extension or no treatment other than recumbency in bed is true negligence. By specifically controlling the individual's activities, one can prevent most of the complications. This is accomplished by turning the patients frequently toward the sound side with the plaster encased leg elevated and supported at the proper angle, or by turning them on their faces, or by moving them from bed to wheel chair and by insisting on setting up exercises including the arms, the shoulders and the free leg and by instructions in deep breathing exercises. Exercise can be furthered whenever the patient is hospitalized by settling up a Balkan frame over the bed together with the so called "bird perch" or "monkey bar." Such apparatus enables the patient to move about in the bed under the power of his own arms and shoulders.

The period of fixation is important. Complete rest of the injured part is of prime importance in its healing. The fixation suggested should be maintained for no less than ten weeks and in many instances should be continued to the twelth or fourteenth week. After the eighth week, one can remove the anterior shell of the cast to just above the knee allowing some action of the quadriceps muscle and massage of the patella. If the *x*-rays taken at the fourth week and the eighth week show no evidence of absorption, one can proceed cautiously with the next step in manage-

ment of this fracture, namely, the beginning of the ambulatory phase. Sitting up in bed, mild active exercises of internal and external rotation, moderate flexion and extension at the knee joint are advocated. Under no circumstances should passive motion be permitted, because by so doing a moderately firm union of the neck of the femur may be resolved into a re-fracture. After a week or ten days of such treatment in bed, the patient is allowed in a chair and as rapidly as equilibrium can be obtained the individual is taught to walk with crutches. The normal rhythm of gait should be insisted upon. The foot of the injured side should be allowed to touch the floor but not to bear weight. In this way the crutches must be carried parallel to the injured leg at all times in order to relieve it from weight and the equalization of the stride range can be the better insisted upon. This is most important. *X*-rays should be taken at intervals when judged necessary by the surgeon. Full weight bearing should not be allowed until the trabeculations can be clearly seen to have closed the line of fracture. The use of two canes when the crutches are discarded is helpful. Following this, dependency may be placed on one cane and finally freedom from any artificial support. The entire conduction of a case may consume four to eight months.

FIG. 6. Application of cotton padding for the coaptation cast.

It is not the purpose of this article to discuss the various types of reconstruction which may be utilized in the event of failure of union. It may, however, be said that there are several such which are most efficient if properly carried out.

To simplify and condense the foregoing, let us conduct and manage a typical case. A woman aged 75 years trips on a rug in her home and injures her right hip. She is seen by her surgeon who because of the type of the fall sustained and her age together with the eversion, slight flexion and moderate amount of shortening makes a clinical diagnosis of intra-capsular fracture of the neck of the right femur. He may apply a Thomas splint for transportation to a hospital or may transport her with the aid of sand-bags to the institution. There she is immediately *x*-rayed on admission in order to prevent unnecessary moving later. The clinical diagnosis is confirmed by the *x*-ray. She is transferred to her bed and either sand-bags or a very light Buck's extension is applied to relieve muscle spasm and make her more comfortable. In cases of extreme pain, a small dose of morphine may be administered. She is given a general physical examination and if the condition warrants, she is given an enema or a mild cathartic to evacuate the

bowel. Fluids are at once started in large quantities, either by mouth or glucose intravenously. Dehydration is thereby instituted. At the tenth week she is removed from the cast carefully and an *x*-ray taken without plaster. If her position is

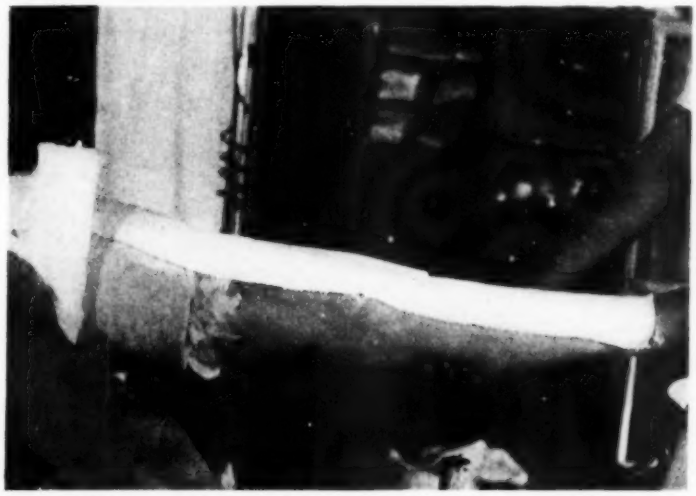

Fig. 7. Felt around the pelvis and groin and plaster slab applied directly on the skin. Following this, a typical spica plaster cast is applied as usual.

checked in its infancy. As soon as she is relieved of any great shock or great apprehension and her physical condition justifies it, she is taken to the operating room, given an anesthetic and placed on a fracture table. The left leg is then fastened firmly in the stirrups and abducted about 25 to 30 degrees. The reduction is carried out and verified by the heel-palm test. A plaster spica is then applied. Post-reduction *x*-rays are taken before she is returned to her bed. No opiates should be administered after these steps are completed, but careful attention should be given to elimination and the continuation of sufficient fluid intake. Orders are left for mild sedatives—½ grain of codeine or 10 grains of aspirin or both. She is given a light diet and an enema whenever necessary for the first few days. When she has adjusted herself to her new environment, she is turned on her side or abdomen several times daily. She takes moderate setting-up exercises of the arms and shoulders together with deep breathing twice daily. At the fourth week she is *x*-rayed again to confirm maintenance of position. At the sixth or eighth week the cast is half-shelled to a point just above the knee and massage and mild quadriceps exercises are satisfactory, and there is evidence of healing, she is allowed very mild active exercise of the injured leg for the next ten days, following which she is placed in a wheel chair for once or twice daily for about a week. At the twelfth week she is allowed up on crutches and is specially instructed as to walking. Due attention is paid to the regular rhythm of gait. No weight bearing is allowed on the injured leg but she is allowed to touch that foot to the floor. At the sixteenth week another *x*-ray is made and if union is found to be good, her weight bearing is rapidly increased. Otherwise, she continues as before. Gradually the crutches are discarded, two canes are substituted and finally one. In the event of non-union or absorption, the question of reconstruction is immediately taken up with the patient. At about the end of the sixth month she has served her apprenticeship and is either well with a sound hip or is facing a surgical procedure.

By the method herein described one can depend on between 70 per cent to 75 per cent excellent results. This figure, however, probably represents all that can be obtained by such conservative means. For higher percentages, it is possible that we

may turn to the various open and semi-open techniques.

In conclusion, a few words of warning may be pertinent.

Do not allow the patient to wait long without splinting or traction.

Do not fail to make a general physical examination.

Do not use opiates in elderly individuals.

Do not apply a too heavily padded cast.

Do not allow patient to remain recumbent without exercise.

Do not fail to change a loose cast.

Do not allow patient to bear weight until evidence of union or of irreparable non-union appears.

Do not be too fatalistic about these fractures.

"The invasion of the clot by connective tissue takes place from all sides; that is, from the surrounding tissues and from the periosteum and from the medullary canal."

" . . . A fracture is temporarily healed by callus and then this callus is invaded and replaced by the ultimate bone which usually begins at the junction of the stripped-up periosteum and the shafts and grows toward the bone defect."

OPERATIVE TREATMENT OF HIP FRACTURES

INTRACAPSULAR

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UNDER this title no one can write with authority or with certainty, as yet. For twenty years, and more, good men have wrestled with this problem, without much real satisfaction. Many claims have been made and are being made, more and more, that the experienced amongst us are hesitant in accepting. It *cannot* be that good!

Fracture of the hip, of the femoral neck, intracapsular or sub-capital, or near that, is, and perhaps always will be, not only a major calamity but a major problem for us all.

This article is premature, no doubt, in that we still do not know the best way to treat hip fractures. And one must not be too optimistic.

Predominantly hip fractures occur in the aged and infirm, and the intracapsular fractures—which alone concern us just now—involve problems of circulation, nutrition and repair that give us uneven results even in the vigorous middle-aged when they suffer this injury. A lamentable mortality (due not to the lesion, but to the type of folk who are most prone to fracture hips) we can reduce, but not abolish. Moreover, anatomic repair does not really ensure functional return in these old and often feeble people.

It is a rather grievous chapter, this of hip fractures in older folk—something has to be done for better results. When one contrasts today's results with those of the early years of the century, he finds that we have come forward, and a good way forward.

Hip fracture no longer means condemnation to the chair—the wheel-chair—in the way it once did. The achievement of such progress as has been made, has been in the face of curious difficulties.

In the first place arose the amazing difficulty in educating the profession to distinguish between extracapsular and intracapsular types. Long after the turn of the century this had not been accomplished. Today the accomplishment is not complete, and there is still much confusion.

Of course the fact is that the extracapsular fractures present no nutritional problems, unite promptly almost without exception, and demand nothing but rest for a few weeks and avoidance of malposition of fragments under muscle pull.

This resulted in utter confusion as to the Phillips-Maxwell-Ruth method and the results thereof, for example, and it is to be feared that the same confusion has made difficult any estimate of the value of Roger Anderson's traction apparatus, undoubtedly legitimate and efficient in the extracapsular type.

Strangely little was done about treating hip fractures until early in this century. There were really no methods.[1]

Whitman dealt with a postulate that abduction produced fixation by contact of neck and acetabulum. He spoke of it as a reduction but it must be only in an occasional case that this maneuvre really reduces. Whitman used the single spica plaster for fixation in a favorable position of abduction. There is no question but that abduction is the optimum position (the writer knew that and used it) the best way to neutralize cross-pull by muscles, and to avoid adductor contracture.

[1] The Phillips-Maxwell-Ruth method of abduction traction came first, perhaps, then Whitman's work and the writer's.

Admirably publicized, this method had vast vogue, and is widely used. Data as to results are conflicting and meagre. Reggio's

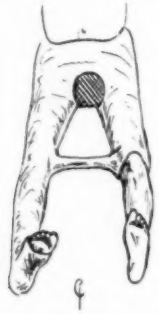


Fig. 1. Double spica.

Massachusetts General Hospital data and the questionnaire reports of the national associations seem to discredit a bit the rather positive claims put forth. It is because the results have not been satisfactory that Kellogg Speed wrote about the "Unsolved Fracture."

The writer was very early intrigued with the problem, working on it from a different approach, trying to get results by frankly "breaking up" all impactions not definitely satisfactory.[2]

There was then developed the principle of artificial hammer impaction, now considerably practiced. It is possible, as is easily proved, to produce a mutual interpenetration of fragment surfaces—an impaction not deep, but sufficient to maintain the reduced position against reasonable handling of the limb.

The third thing stressed by the writer was the use of the *double* spica, seemingly the only way to *maintain* abduction.[3] This was kept on for four months, then a "convalescent Thomas" brace was used. (See Figs. 1 and 2.)

The results were better—how much better, the old records of the City Hospital make it hard to estimate. That was before the day of follow-up clinics.

[2] It was early recognized that the type of impaction with only a spike point driven into the head had no mechanical value and was to be disregarded.

[3] The single spica, not fixing the pelvis, allows side slip and consequent *ad*duction as padding and fat shrink away.

We *tried* for reduction and the impaction helped notably, but the actually recorded data are of no real exact value. Only very

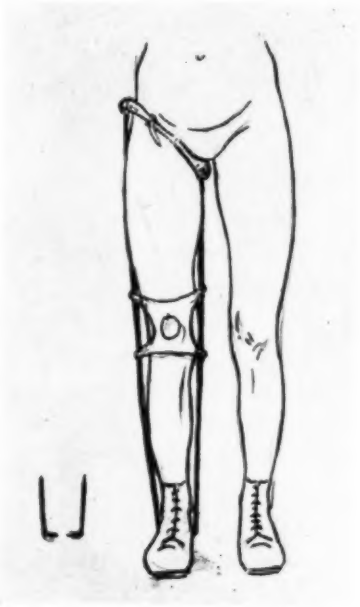


Fig. 2. Convalescent caliper.

lately have we all realized a factor—a very vital factor that we had overlooked—a factor only brought out when we got "lateral" views.[4] This factor is that of the forward *translation* (*miscalled rotation*) of the proximal fragment. (See Fig. 3.)

Very usually, this displacement brings the fracture surfaces clean out of contact, even though the anteroposterior *x*-ray view may seem to show excellent alignment of fragments. Correction of this displacement is in itself good treatment, and Fay reported a series of excellent results in cases in which he had reduced and done nothing more than apply the mechanically not very efficient plaster "boots" and cross-bar. Certainly this exact reduction is a prerequisite for any further treatment, operative or other.

Leadbetter and the writer independently and about the same time worked out methods of reduction curiously similar. It

[4] Leonard apparently was the first to get (with his "cassette") good working lateral views, though the Johnson technique was earlier. Now there are a half dozen efficient methods.

is a question of rotation and leverage. (See Fig. 4.)

To go back, years ago there was a period

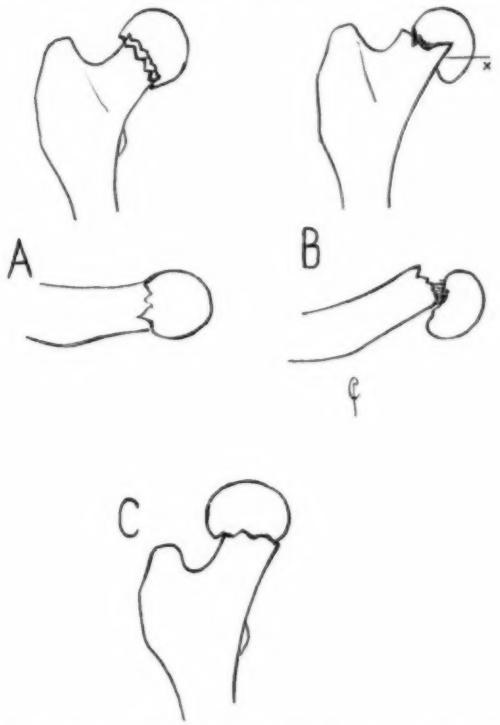


Fig. 3. A, impaction by mutual penetration of fracture surfaces (pretty sure to unite). Anteroposterior and lateral views. B, the usual impaction (by penetration of only a spike point of the lower fragment well up in the head). Lateral view shows rotation of neck forward. The shaded surface at *x* is fibrous periosteal surface useless for repair. (This type, unreduced, usually fails to unite.) C, valgus impaction. This type is the most favorable and almost always unites.

when much spiking was done, much insertion of bone pegs—autogenous and other. The writer shared in this with some excellent results, but with an average no better than that of the others. We used nails and bone peg insets, autogenous or foreign. The results were discouragingly uneven, including too many breakdowns *after* the flag of victory was up, and these were none too few. The fact, of course, was that our methods—based on little knowledge—were too crude.

Presently, Smith-Petersen, ingenious surgeon mechanic, devised his nail, a distinct contribution to our "armamentarium." This is a three flanged nail with wedge flanges: once in, it certainly gives fixation and controls rotation. (See Fig. 6.)

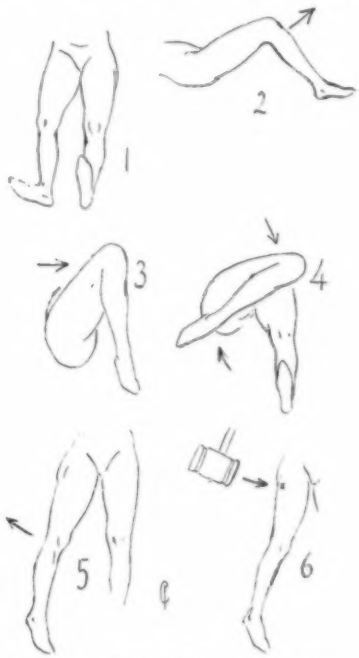


Fig. 4. Reduction, intracapsular fracture. (1) Original deformity. (2) Traction in slight flexion. (3) Adduction. (4) Inward rotation. (5) Extension with internal rotation preserved. (6) Artificial impaction.

He has reported admirable results in a series of cases,—so good that one wonders whether they were "run of the mill" cases. The writer has always felt that the elaborate operation was a heavy toll for old ladies to pay, and that the cross section of the nail driven in must of necessity, by wedge action, compact a large part of the cross section of the neck into crushed bone as incapable of repair as the cylinder so often left behind by Steinman pins, produced by similar wedge compression.

It is to be borne in mind that there is no callus formed in these fractures: repair (end-osteal) depends *entirely* on the cross section of undamaged bone surfaces in contact across the fracture line.

Later, Johanson simplified the Smith-Petersen technique by setting in a guide of Kirschner wire, over which the Smith-

Petersen nail, previously perforated, was driven home.

Böhler has taken up this technique.

Fig. 5. Artificial impaction with the hammer.

There is no question but that if one wants a Smith-Petersen nail, that is the way to set it in.

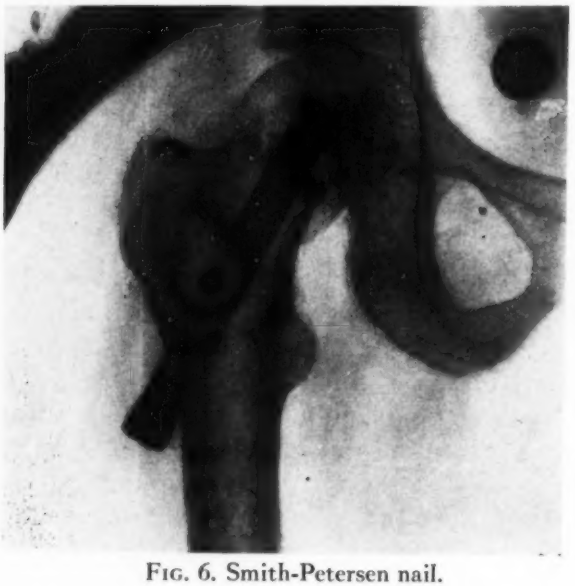


Fig. 6. Smith-Petersen nail.

About 1933, with more exact knowledge of lesions, with more efficient methods of reducing displacement, with better fluoroscopes, open operating of the "blind-nailing" type began to be reported by many men, and the devising of trick nails, screws, and other gadgets still goes on.

Perhaps here, as so often, the exact gadget used is not of so much importance as the way in which it is used.

Seemingly the pioneer was O'Meara of Worcester, Massachusetts. He, as others since, used Kirschner wire or its equivalent. This has proved not[5] inefficient but a bit dangerous in other hands.

The late E. Denegre Martin devised a method that produced excellent results. He used wood screws.

Austin Moore has reported almost unbelievable success using a special nail.

Gordon Morrison and the writer have been reducing and nailing for over two years with satisfactory results[6] and many

[5] See J. B. and J. S. 1937. Note of late penetration of pelvis by wire,—the wire recovered by operation from the pelvic side.

[6] Not yet reported. No reports are worth much in which the most recent case is under two years old.

others are working on the problem with techniques different in detail.

Our technique is to allow a five days' wait, to allow for recovery, for passing of the period of abdominal distention and adjustment of circulation to bed conditions.[7] Then, there is preparation of the field about the trochanter in the usual way.

Fig. 7. Blind nailing.

Fig. 8. Excessive absorption with usury of bone and penetration of acetabulum by nails. Notwithstanding this, union progresses. Nails now out; union firm.

The patient is taken to the fluoroscopic room, anesthetized with "G.O. ether" or often with spinal anesthesia. Then it becomes a two surgeon job. One reduces and holds, and, as the surgeon becomes experienced, this reduction grows to be very exact. A check record plate is then taken.

Then the fracture is impacted, using a *slow* swinging blow with a big *heavy* mallet over the trochanter (see Fig. 5). Felt may be added to the protection of the preparation towels; in any case there is never even any bruising. The impaction is repeated until one feels a slight "give" in the bone.

Then the surgical field is made ready, a short incision made by surgeon number two (number one still holding), just over and below the trochanter. With the foot rotated inward at about 25° the neck is horizontal.[8] A long drill is set in below the trochanter, its course checked at intervals by a short look with the fluoroscope.

The surgeon holding can tell by touch, with curious exactness, what quality of bone is traversed, when the fracture line is reached, and, by a curious sort of reverberatory vibration, when the drill is well within the head. Moreover if, as may happen, the drill misses bone, he knows that instantly.

The drill is pushed fairly well into the head, withdrawn, and then a 3 to 3¼ inch steel nail of the Böhler type is driven in the drill hole, a second drill and nail a half inch away. The wound is then closed and dressed.

[7] This at least in the older and less vigorous patients.

[8] With the line between internal and external malleoli parallel with the table, one comes out pretty exactly right.

We use no apparatus except pillows for comfort. Patients are in a chair within three days and encouraged to move the

Fig. 9. Usual picture in cases of non-union. The neck seems entirely gone; in fact, the outward rotation position prevents a true view. Usually, but not always, a fair bulk of neck is left.

Fig. 10. Good result in reconstruction operation.

limb, which they do according to their strength and interest. As soon as may be they are up and walking with a chair,[9] *but* no weight-bearing is allowed for some months. No doubt early weight-bearing such as Moore advocates will work very often. Under the conditions in which we are working, however, we see no point to it, and some risk.

We have had deaths, a couple of failures, and several slow results, *but* on the other hand, in end-results as to union and a reduction in complications, we find a gain in well-being and comfort of the patient, a great gain in flexibility and function of the convalescent limb.

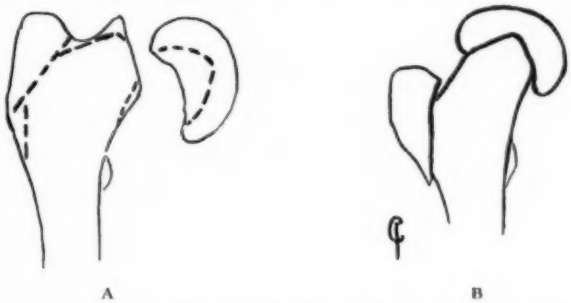
[9] Old ladies handle crutches poorly almost without exception, but can stand behind a kitchen chair, lean over and push it over a smooth floor. That is the best crutch.

There are problems of slipping, breaking of nails, absorption of the distal fragment and consequent pushing in of the nails, that must be studied and warded against. The nails hold in the distal fragment, push through the head if there is absorption. We are using shorter nails lately.

Our hope that good—even perfect—reduction would solve the problem, has "let us down." My hope that perfect reduction *plus impaction* was the answer, proved, at least in part, untrue.

There is one more point as to reduction, perhaps best taken up here. It has been long known that broken hips with "valgus" position seemed always to unite by bone. There is a matter of original mechanism, of minimal displacement that we can hardly go into here, but it is obvious that this valgus position gives the most favorable holding against muscle pull. Muscle pull, in such cases with valgus position, *compacts, not disrupts.* We can now ensure valgus position pretty much at will.

There must obviously be an advantage in this and in the impaction with which we follow it, but of course even this cannot



A B

Fig. 11. Brackett operation. A, the incisions and reshaping. B, the completed reconstruction. There is no objection to fixing both head and trochanter fragment with screws.

ensure union. There are the nutritional elements to reckon with. These are, it seems, almost entirely circulatory.

Overcome by the howl as to vitamins, even the least convinced have used them freely. The net result of vitamin D, with fish oils, may have been little, may have been nothing, or may have resulted in more lime in arteries. And the vicious absorptive process goes on—typically[10]—always at the expense of the proximal end of the distal fragment.

So, we have come so far only to reach an obstacle of which we know little if anything. We have solved the matter of lesions, of displacement, pretty well—we can deal with replacement, steadying by impaction, fixation with nails by an operation easily withstood by even feeble patients.

We have simplified convalescence. We have definitely improved results with at least *better* local results—results one may call at least very decent.

It is fair to say that in the end "blind" nailing or screwing must supplant more conservative or more radical methods in the general run of cases, particularly in the elderly. This avoids: (1) The shock of the heavier operations; (2) The ruinous immobilization and confinement of the older conservative methods.

[10] Though some cases show no absorption at all.

As yet the matter of circulation and the subsequent prospect of either prompt repair or absorption is still "on the knees of

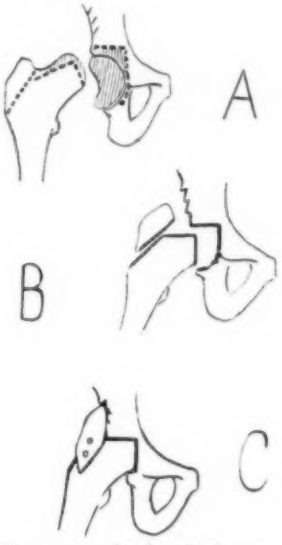


Fig. 12. Arthrodesis. A, various cuts: slanting trochanter cut, cuts to square the neck, and horizontal cut to form roof of the socket, with the ragged line left as the acetabular cartilage is torn out. B, parts ready to put together. C, final position. Note the slight abduction.

the Gods"—dependent, no doubt, mainly on the amount of tearing of the vessels of the neck, and on the quality of the vessels left intact.

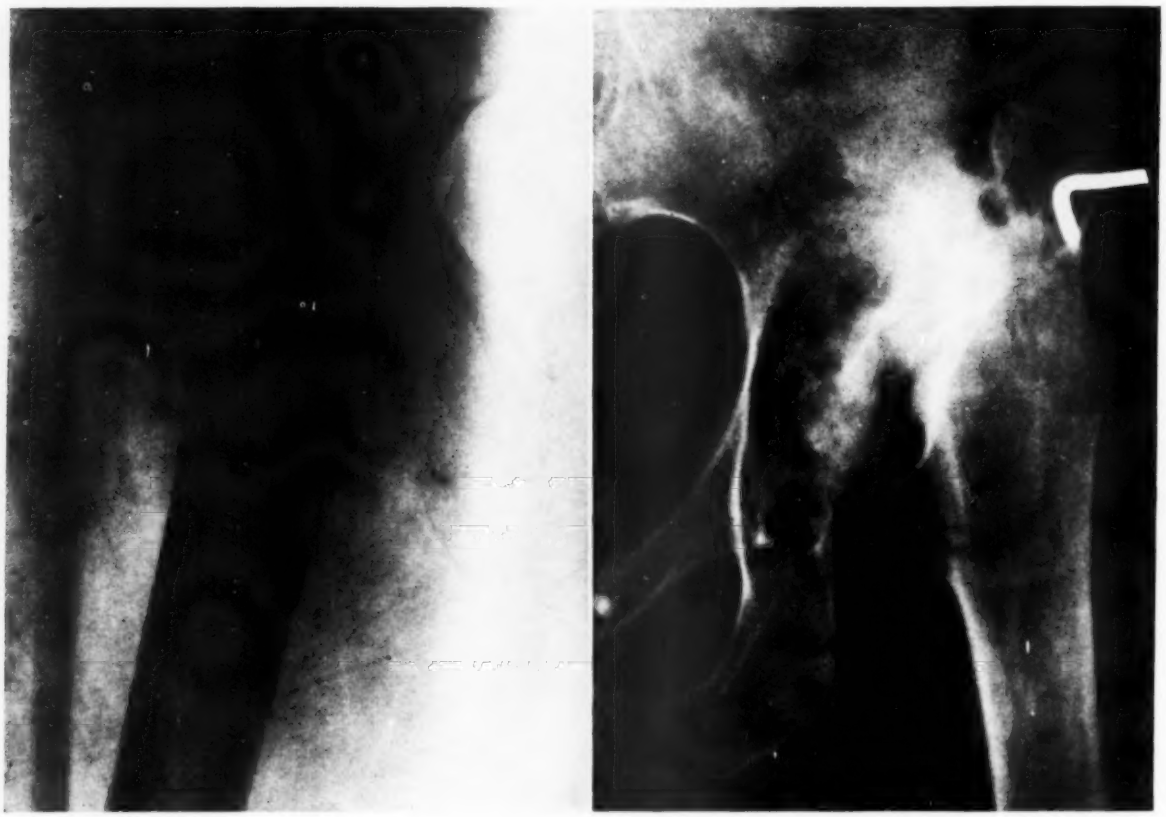
It seems that all we can do is to work for proper reduction or over-reduction, approximation of surfaces by impaction, fixation with metal pins or screws that give fixation, efficient especially against rotation, with the least possible destruction of the bone of the neck on which we must in the end rely, for our repair.

I submit that so far no one has had the wit to contrive any tool that will fix adequately and yet keep up with the loss of neck length by absorption.[11] (See Fig. 9.) The problem being mechanical is pretty surely soluble.

[11] The Denegre Martin technique is the only attempt to solve this but this, good as it is, can not give quite ideal fixation.

In the meanwhile it is fair to say that "blind nailing," in one form or another, has come to stay. The results seem better

Certain fortunate cases achieve painless fibrous union. To these no operative proposal has anything to offer.



A B

FIG. 13. Arthrodesis. A, union almost complete. B, end result in another case.

measured in bone terms, are far better in human terms, and far better in ultimate function.

The problems remaining are technical, likely to be solved in the near future.

Some day we may reach Utopia.

Meanwhile we can offer to these poor ladies a treatment offering at least *better* prospects, a treatment involving no measurable operative shock or risk—substituting for the long torture of the spica, at least a comparatively comfortable convalescence.

OPERATION ON CASES THAT HAVE FAILED TO UNITE

Just a few words before closing as to operative work on cases in which union has failed.

To the others with fibrous union or none, with a useless and painful hip, what can we offer? There have been countless operations proposed.

The simplest thing of course is Boszan's blind multiple drilling. He shows excellent results, but mainly in the cases of *delayed* union rather than the old failures.

For *frank non-unions* we must usually do more.

The writer years ago operated on two cases of non-union by wide removal of the capsule and packing of a curetted bone-gap with small chip-grafts.

Otto Hermann has done this on my old service at the Boston City on one more case. In all three, union was secured. This attempt is worth further study.

As to frank non-unions: time enough has gone by, cases enough operated, so that

we should have made up our minds by now. The choice as I see it is between an operation of the Brackett type and an arthrodesis of modern type.

No doubt there have been admirable results from late refreshing and nailing, but the results are so uneven, the less favorable results so unsatisfactory, that one can recommend the procedure rarely if at all.

The same holds true, one suspects, of the so-called Whitman "reconstruction"—really an excision—of the hip, which has not done well in my hands. In Figure 10 is represented the only case that did well, and he not too well.

Colonna's operation sounds better, avoiding perhaps the absorption of neck and the riding out of the distal fragment from the acetabular cup.

Of Putti's operation and the whole "bifurcation" group, the writer has no personal experience.

In the real old completed non-unions we have two roads to choose from:

1. The Brackett operation. Long ago Dr. Brackett conceived and demonstrated an operation, and one which worked, for certain un-united hip fractures. Since then, he, Cotton, Speed and particularly Magnuson have used this method.

The essence of this operation is shown in Figure 11. Magnuson's experience agrees with that of the writer in that the minority of cases in which one does not get bony union uniformly get useful limbs, often with good motion, and with power, even in abduction.[12]

2. Arthrodesis. In regard to this let us say (a) Loss of motion means nothing to these patients who lost it long ago. Moreover, loss of hip motion gives an astonishingly small loss of efficiency.

(b) Modern technique makes this a definite procedure of predicable results.

The writer, years ago, did arthrodeses (old type) that didn't freeze in more than three cases in four. The fourth case one remembered, or was reminded of.[13]

Result of this was the contriving of an operation combining Hibbs' extra-articular Albee's old plan of squaring, and a new item claimed by the writer. Figure 12 should explain most of it.

The essence of it is that one goes in one quarter to one third inch *above* the acetabular edge, from the side, horizontally, with a very broad chisel, goes in as far as he should, one half inch farther, kicks *up* the heel of the tool with the heel of his hand, and *tears out* the whole cartilaginous floor of the acetabulum.[14]

The detail of squaring the head, transplanting the trochanter and attached muscles into the gap between femur and pelvis should be obvious from the figure. The writer is apt to peg the trochanteric fragment *to the femur*, to a freshly-cut surface, a bit forward, over the ex-joint.

All the cases have done well. One, *over-eager*, got a fibrous union. Function was good: she is happier than I about it.

CONCLUSION

To conclude, hip fracture remains, as always, a calamity, but modern methods pressnt such improvements that we can promise, to fresh cases, better results from methods involving no shock of operative procedure. There is no wearisome fixation in vast spicas of plaster. There is an easier convalescence, and not longer than that by older methods; there are better functional results.

Even with results only *better* as to bony union, this leaves us heavy winners in terms of living and comfort.

And that is where we stand.

[12] Magnuson has done these operations on cases much earlier than the writer has chosen, and produced results. These were cases that evidently *were not going to unite*, I have no quarrel with his judgment in this.

[13] And this applies, of course, to arthrodeses for senile hypertrophic arthritis as well as ununited hip fracture. Failing bony union they went on to slow permanent flexion and adduction.

[14] Reason for this: the acetabular floor for ¼ in. plus, is more fibro-cartilage than bone. Curetting it is wasted time, and, curetting done, one has a surface with no repair capacity. Our way, one tears out all this stuff, reaches viable cancellous bone, fit for repair growth.

As to the later cases, the ununited, we can promise some help. Most of them, if they are reasonable "surgical risks," can be helped. Many can be made efficient for "light house duty." Not a few can be returned to efficiency.

EPICRISIS

One realizes that this article falls short of certain joyous notes that one has heard.

However, we have come a long way since the old days. We know a little bit about what we're talking about, have something definite to offer, even without guarantee—know what we have to fall back on in case our first best fails us.

And that, I submit to you, gentlemen, is no little thing to offer.

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"External violence applied directly to the jaw in fights, sports, falls, and traffic accidents accounts for most fractures. . . . Fractures may occur in areas weakened by pathologic processes such as osteomyelitis, benign cysts and tumors, and malignant growths inherent in the jaw itself or secondary involvement, as from a carcinoma of the buccal mucosa."

NON-OPERATIVE TREATMENT OF FRACTURES OF THE SHAFT OF THE FEMUR

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THE closed reduction of fractures of the femoral shaft is difficult because of the numerous mechanical factors involved. The fundamental mechanics of traction and immobilization, involved in the correction of the various deformities arising in this fracture, were fairly well defined in the writings of the early Egyptian and Greek physicians. Modern methods of reduction of greater or lesser complexity are simply modifications of these original procedures. The purpose of this paper is to outline the general principles involved in the diagnosis and treatment of fractures of the shaft of the femur by closed methods. An evaluation of the various proved methods will be attempted in the light of our experience and the published work of others. The criticisms and opinions exhibited are based on the current practice at the Pennsylvania Hospital of Philadelphia on the surgical service of Dr. Walter Estell Lee.

The importance of fractures of the femoral shaft, stressed in numerous articles on the subject, cannot be overemphasized. Occurring most often as the result of direct violence suffered in motor and industrial accidents, or in falls from heights, the patient suffers from at least a moderate degree of surgical shock along with his local lesion. The management of such a major surgical catastrophe often taxes the judgment of the most experienced surgical minds. It is imperative, therefore, that these patients should be treated immediately by a senior surgeon and never delegated to the care of relatively inexperienced, though eager, internes and junior surgeons. This policy has been adopted by many hospitals which maintain separate fracture services, as well as by several of the larger industrial concerns with private clinics and hospitals. The excellent results of fracture treatment in these specialized units speak for themselves, and should afford an incentive to other surgical groups, interested in the improvement of fracture treatment, to adopt similar practices.

Another aspect of this phase of the subject which deserves special comment is the management of fractures of the femur in elderly patients. The old tendency to neglect the fracture and treat the elderly patient, which was exploded by Whitman's great contribution on the treatment of fractures of the neck of the femur, must also be decried in the handling of fractures of the femoral shaft. The older the patient, the greater the challenge to our ingenuity to discover methods for adequate treatment of the fracture, while at the same time supporting the declining physical condition.

There is also the need for a word of caution regarding fractures in patients at the opposite end of the life cycle. Fractures in children heal with remarkable facility, and deformities of all sorts are corrected as though by magic. Ashhurst attributed this marvel of nature to the fact that soft parts and bone, arising from the same tissue embryologically, have not become sufficiently differentiated from that parent tissue in children so that they cannot revert to their primitive bone-forming role in an emergency. Whatever the explanation may be, it is not justifiable to be satisfied with an imperfect reduction in a child because of the knowledge that the end-result will be satisfactory. Conwell, in "Acute Fractures of the Shaft of the Femur in Children,"[4] gives a fine exposition of this point of view in the following words; "The general impression that,

regardless of the method of treatment of fractures of the femur in children, good results will be obtained, is wrong. In no instances of any fracture in the body is it so important that proper treatment be given as in the fractured femur of the child. A good limb in a child is more important than in the adult. Its psychic effect is very important and a disability works grave hardships on the youngster."

One frequently hears the statement that children will "outgrow" fractures, as an apology for a poor reduction. While this may be a true generalization it disregards the resulting deformities which often persist for years, and occasionally are never "outgrown." The abnormal weight-bearing lines, resulting from improperly reduced femoral fractures, frequently cause compensatory abnormalities in the structure and mechanics of the pelvis and spine which become permanent disabilities.

ANATOMY

Before considering the methods of treatment for fracture of the shaft of the femur it is essential to review briefly the anatomy of the bone and its attached muscles. The normal contour of the femur, viewed from the lateral aspect, takes the form of a curve, more marked in the lower third, convex anteriorly. This curve must be restored after fracture in order to avoid disturbance of the normal weight-bearing lines of the body. In the event of failure to restore this curve, strains of the spine, hip, knee and foot of varying severity may arise. Furthermore, there is a slight curvature, convex laterally, on viewing the femur antero-posteriorly. The angle made by the neck with the shaft is about 120 degrees. A decrease in this angle, which may occur following a fracture in the intertrochanteric region, results in a varus deformity with shortening of the affected leg, and compensatory tilting of the pelvis towards the affected side. The compensatory scoliosis of the spine is a secondary complication.

The positions of the fragments after fracture, and the maintenance of a satisfactory reduction, are determined almost entirely by the actions and counteractions of the powerful thigh muscles. Gravity plays a less important role, especially in the occasional sagging of the thigh in fractures of the middle third of the shaft. The positions assumed by the bone fragments in fractures at varying levels are fairly constant, and may be briefly described as follows:

(a) In intertrochanteric fractures the short upper fragment is abducted due to the action of the gluteus medius muscle and externally rotated by the short rotators attached to the greater trochanter. If the lesser trochanter remains attached to the upper fragment, there may be a certain amount of flexion as the result of the action of the ilio-psoas group. The shaft fragment is pulled upwards by the muscle groups reaching from the pelvis to the middle and lower portions of the shaft and to the leg, thus producing varying degrees of shortening.

(b) Fractures involving the upper third of the shaft produce a characteristic deformity. The short upper fragment is externally rotated and abducted by the muscles inserting into the greater trochanter, and also flexed by the action of the powerful ilio-psoas muscle attachment to the lesser trochanter. The lower fragment is pulled upwards by the combined actions of the hamstring, quadriceps and adductor muscles, and, in addition, adducted by the adductors longus and magnus. Therefore, the essential principle of reduction in such a fracture consists in bringing the lower fragment, which can be controlled, into alignment with the short upper fragment, which cannot be controlled. Hence, the lower fragment must be placed in abduction and external rotation.

(c) In fractures of the middle third of the shaft the position of the

fragments is not definitely predictable. Shortening is fairly constant, and the lower fragment tends to be displaced posteriorly due to gravity and the action of the gastrocnemius muscle. The angulation of the fragments in a lateral plane varies with the level of the fracture and the strength of the muscles. In fractures of the lower middle third and lower third of the shaft, the lower fragment is often pulled upwards with its upper extremity displaced laterally to form an angle, convex laterally, with the abducted upper fragment. This deformity is due to the action of the adductor longus muscle which tends to shorten the distance between the adductor tubercle and the pubic bone. In this event it is important, as pointed out by Mahorner and Bradburn[16] to adduct the lower fragment in order to relax the adductor muscle, and thereby allow realignment in the sagittal plane. Attempts at reduction by abduction of the lower fragment would simply increase the deformity.

(d) In supra-condylar fractures and fractures of the lower third of the shaft there is most often posterior displacement of the lower fragment due to the attachments of the tendons of origin of the gastrocnemius muscle in the supra-condylar notches. The long upper fragment is not angulated laterally as a rule, but is often pulled down anteriorly by the contraction of the thigh muscles as a group, resulting in considerable overriding of the fragments.

DIAGNOSIS

The diagnosis of fracture of the femur is usually obvious from the history of the injury and the disability of the affected leg. Shortening is almost always present, and the degree can be determined by comparative measurements from the anterior superior iliac spines, or umbilicus, to the internal malleoli. In taking such measurements accuracy is improved by marking the skin over the bony landmarks and holding the measuring tape over such marks. This technique avoids errors, due to the mobility of the skin and the consequent variability of the measuring points, which occur when one relies upon palpation alone. In intertrochanteric and high shaft fractures a comparison of the lengths of the base lines of Bryant's triangles may be helpful in establishing the presence of shortening. Local signs, such as the acute tenderness at the fracture site, and the swelling due to muscle contraction and hemorrhage beneath the fascia and into the muscles, are not completely reliable because of the presence of such evidence in severe contusions. The marked eversion of the foot and leg, and the frequent absence of the normal anterior bowing of the shaft are characteristic. In the majority of cases, one can approximate the level of the fracture with sufficient accuracy by means of careful inspection and notation of the signs above enumerated. Manipulations, either rotary or angular, to determine the site of the fracture are to be condemned both because they cause unnecessary pain and because of the danger of inflicting additional injury to the soft parts by movements of the jagged bone ends. Crepitus should never be elicited intentionally.

The final diagnostic aid is the *x*-ray. *X*-rays in anteroposterior and lateral planes should be obtained in every case before treatment is undertaken in order to determine the level of the fracture, the position of the fragments, and the possible presence of small intermediate fragments. Since the taking of *x*-ray films involves moving the patient, an emergency splint, preferably a Thomas splint with traction applied to the foot, must be applied before such moving is carried out. Fluoroscopic examination generally affords adequate information regarding the fracture, but in view of

possible legal complications it is a safer policy to have a film as a record of the pre-reduction position of the fragments.

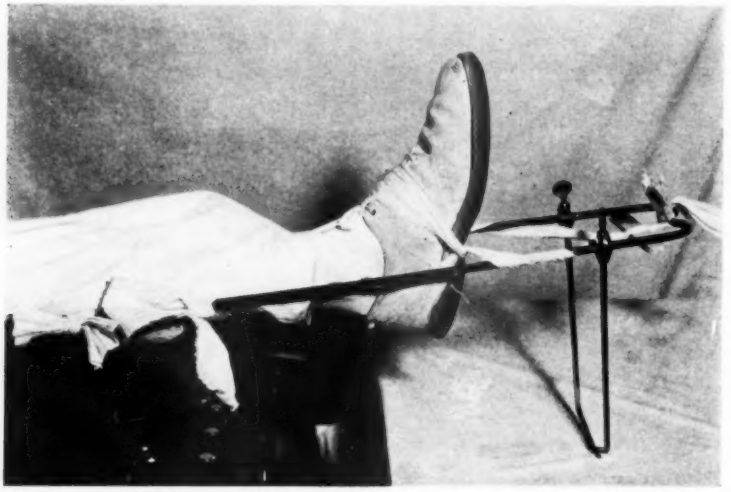


Fig. 1. Double-loop hitch applied for emergency traction in a Thomas splint. Note that dorsiflexion of the foot is obtained by the pull of the band overlying the heel.

TREATMENT

The treatment of fractures of the femur may be divided into two distinct phases, one of which is concerned with the immediate emergency treatment, and the other with the later reduction and permanent fixation.

Emergency Treatment. The primary consideration in an acute fracture of the femur is the general condition of the patient. A thorough examination to determine the physical age and state of health of the patient is essential, because the type of treatment will vary with these factors. This procedure may be postponed temporarily in severe cases until the acute problem is well in hand. The presence and degree of shock are noted and supportive measures are undertaken at once. Morphine is administered to relieve pain. Unless the shock is so profound that the slightest manipulation is dangerous, the next step is to splint the leg. The importance of immediate splinting cannot be overestimated. Immobilization of the fragments is the best method of combating shock and affords the patient relief from the pain caused by the movement of the fragments. An equally important justification for the emergency splint, especially when the traction factor is utilized, is the minimizing of muscle contraction. Thus the length of the limb is maintained and overriding of fragments, which may be difficult to overcome after muscle spasm has occurred, is prevented. When traction has been applied within minutes after the fracture has occurred, the *x*-ray frequently reveals the fragments in practically anatomical alignment. Occasionally it is difficult to maintain such good alignment during the transition from the temporary to the permanent traction apparatus or plaster fixation.

The ideal emergency immobilization is carried out by placing the affected leg in a Thomas splint and applying traction to the foot. By exerting manual traction on the ankle, while the ring of the splint is carried up over the leg, one causes very little additional discomfort to the patient. It is important to have the ring of the splint rest snugly against the tuber ischii, which serves as the base against which traction is applied. Any of the popular types of hitches are satisfactory for temporary foot traction, provided the dorsum of the foot and the Achilles tendon are adequately padded. (Fig. 1.) Mastery of one of these traction hitches, so that it

can be applied rapidly when the emergency arises, will prevent embarrassment and save time. Dorsi-flexion of the foot may be obtained by means of special metal foot pieces attached to the splint, or by the use of various slings or hitches. The position of the foot is not important in the average case, since the traction apparatus is utilized for a relatively short time.

In the event that a Thomas splint is not available, the Liston type board splints may be utilized. The lateral board should extend from the axilla to a line six inches below the sole of the foot, with adequate padding along its entire length, but especially in the axilla and flank. This splint affords good immobilization of the fragments, but allows less efficient application of traction, and is therefore not as satisfactory as a splint of the Thomas type.

It may be fitting at this juncture to make a plea for more widespread education of the lay public in the matter of the emergency treatment of fractures, especially those involving the lower extremity. The natural primary impulse to assist the victim of an accident to his feet, or to lift him carefully into a waiting automobile, in spite of an obviously disabled leg, cannot be too strongly condemned. How much more kindly to sit down on the street beside him and exert gentle traction on the injured leg until help arrives with suitable splints. If this doctrine were more widely advertised many patients would be spared additional trauma to blood vessels, nerves and muscles at the fracture site and occasionally compound wounds would be prevented.

Elective Treatment. In every fracture of the femur hospitalization is essential. *X*-ray and fluoroscopic equipment, as well as the requisite apparatus for securing and maintaining reduction, are necessities for treatment which are not available outside a hospital. The many nursing procedures incident to these cases, and the appropriate physio-therapeutic measures, so valuable during both the early and late stages of fracture treatment, cannot be carried out conveniently in a private home. Unfortunately, the prolonged hospitalization makes the treatment of a femoral fracture an expensive proposition.

Except in the rare clinics in which it is customary to immobilize all fresh fractures in circular plaster splints, without attempting reductions until the swelling and acute symptoms have subsided, all authorities are unanimous in the feeling that immediate reduction and fixation are the procedures of choice. We subscribe to this latter policy. The ease with which even the most marked deformities can be corrected within the first few hours after a fracture, before muscle spasm, extensive hemorrhage and leukocytic infiltration with its resultant stiffening of muscles and fasciae have occurred, is sufficient justification for early reduction. Several methods of reduction and fixation are practiced with good results. This fact leads one to believe that the skill of the individual surgeon in using a certain method is a more important factor than the method itself. The procedures discussed and recommended here are the more or less classical ones in common use. The two major principles utilized are (1) immediate reduction and fixation in plaster, and (2) reduction by means of continuous traction applied either to the skin or the skeleton.

1. Closed Reduction and Fixation in Plaster. Immediate reduction under a general anesthetic followed by fixation in plaster is an excellent method of handling fractures of the shaft of the femur. Campbell,[3] in 1925, reported a series of simple fractures of the femur treated in this manner with 95 per cent satisfactory results in adults (fifty-four cases), and 97.5 per cent satisfactory results in children (fifty-three cases). It is hard to conceive of better end-results in this particular type of fracture by the use of any method. We therefore recommend this technique for those skilled in manipulative reductions and adept in the use of plaster.

If the case is seen within the first twelve hours, or later, if there is not excessive

swelling, the reduction is performed at once. Extraordinary swelling and ecchymosis necessitate temporizing, with the leg splinted and elevated for several days, until the swelling subsides. In performing the reduction the patient is placed upon a fracture table with the perineal bar in place, and a general anesthesia is administered. Both legs are firmly fixed by means of the foot pieces in about 30 degrees abduction with the hips and knees flexed to about 45 degrees. The knee, with popliteal space well padded, is supported by a knee rest, or is suspended in a sling from an overhead bar. Traction is then applied to both legs until shortening has been corrected. Then, by means of angulating the fragments anteriorly, the bone ends are made to engage. Another convenient method of accomplishing this reduction is to rest the flexed knee of the injured leg over the operator's shoulder, while an assistant exerts pressure on the leg, against the operator's back, to maintain flexion of the knee and anchor the lower fragment. Thus the surgeon's two hands are free for manipulation of the fragments, and traction is obtained by leaning the body weight against the flexed knee. Reduction is accomplished by traction together with angulation and rotation of the fragments—one must always remember to bring the easily controlled distal fragment into alignment with the proximal fragment.

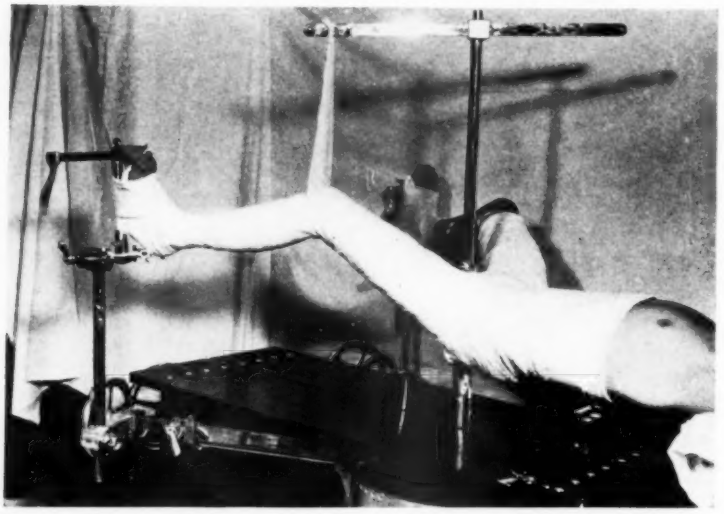


Fig. 2. Bilateral hip spica of plaster of paris for fracture of the femoral shaft. This method of fixation is satisfactory when accurate reduction can be accomplished by manipulation.

A fluoroscopic check of the position is desirable. Engagement of the bone ends, without recurrence of shortening, when the traction is removed and gentle pressure upwards is exerted on the knee, indicates a satisfactory reduction. After reduction has been accomplished, the position is maintained either manually, or by means of the slings and extension apparatus of the fracture table. An adequately padded double plaster spica is then applied, extending from the nipple line to the toes on the affected side, and to just above the knee on the well leg. (Fig. 2.) This plaster is allowed to remain in place for two weeks in children and for three weeks in adults, provided post-reduction *x*-rays show satisfactory position of the fragments. At the end of that time the plaster is removed, the hip, knee and ankle joints are gently manipulated, and any angular or rotary deformities are corrected by manipulating the still soft callus. A similar plaster spica is then reapplied, with the hip and knee joints flexed at slightly different angles, and this plaster is maintained for three to five weeks longer. The plaster is then bivalved and the status of healing at the

fracture site tested clinically. *X*-rays are also taken to check position and callus. If union is progressing satisfactorily, the patient is allowed to lie in bed without support for one to two weeks longer while active motions of the hip, knee and ankle are encouraged by appropriate exercises and physio-therapy. At the end of that time, about ten weeks after the injury, the patient is allowed to walk, either on crutches with a supporting plaster splint, resuming full weight bearing gradually, or more safely with the aid of a walking caliper splint. The crutches and splint may be discarded during the ensuing four to six weeks depending upon the clinical and *x*-ray evidence of firm union. It is important to obtain *x*-rays at intervals of seven to ten days during the first few weeks of weight bearing, so that any tendency towards angulation or shortening at the fracture site may be discovered.

II. Closed Reduction by Means of Traction. This second method for reduction of fractures of the shaft of the femur requires less specialized operative skill, and is therefore more generally applicable than the one previously described. Reduction is obtained by continuous traction on the distal fragment, with the gravity of the trunk and upper extremities serving as counter-traction. Traction may be exerted either through adhesive plaster applied to the skin, or via wire, pin or calipers embedded in the bone. There are definite indications for both methods. In utilizing any traction method, it is essential to place the patient on a fracture bed. This may be a bed specially constructed to prevent sagging, or simply an ordinary bed with a board placed between the spring and mattress. An overhead frame to support the various pulleys, weights and trapeze is also necessary. There are many specialized forms of frames, but the commonly used Balken frame is quite satisfactory. In addition, a Thomas or Hodgen splint is essential to support the fractured limb.

The decision between the use of skin or skeletal fraction has become somewhat simplified since the introduction of the Kirschner wire. When the Steinman pin or ice tongs were the only means of applying traction to bone, there was a moderate danger of infection. With the use of the Kirschner wire, introduced under aseptic precautions, this danger is negligible. Except in adult cases treated by the Russell method, in children under twelve years of age, or in patients with weak musculature, we feel that skeletal wire traction is far superior to adhesive skin traction.

The chief advantages of skeletal traction, as pointed out by Key and Conwell[12] are:

1. It is more efficient.
2. It is more comfortable to the patient and it is more reliable as it does not slip.
3. It permits free movement of the knee.
4. It permits frequent inspection of and free access to the thigh in case of compound wounds or for any other purpose.

The necessity for an anesthetic while introducing the wire is not a serious disadvantage in that a local anesthesia may be used satisfactorily for this procedure. When wires are used in children one must be careful to avoid the epiphyses.

A. The Russell Method. The Russell method of skin traction for femoral fractures was first described in the *British Journal of Surgery* in 1924 by the surgeon whose name it bears. This method has been used extensively on the surgical services of Dr. Walter Estell Lee at the Graduate Hospital of the University of Pennsylvania, the Pennsylvania and Germantown, (Philadelphia) Bryn Mawr (Bryn Mawr, Pa.) and Burlington County, N. J., Hospitals, following a report by Summey in 1931 of the end-results of fifty-eight cases so treated. A report of the anatomical results obtained by this method, in fifty-one cases from these various hospitals, was made by Lee and Veal in 1933.[13] Since that time certain limitations of the Russell method have been appreciated and although less frequently used now, it is still considered the method of choice in certain types of cases.

A description of the exact technique is lengthy and may be studied more advantageously by consulting Russell's original overhead pulley making an angle of 120° with the thigh. This angle varies somewhat with the individual fracture.

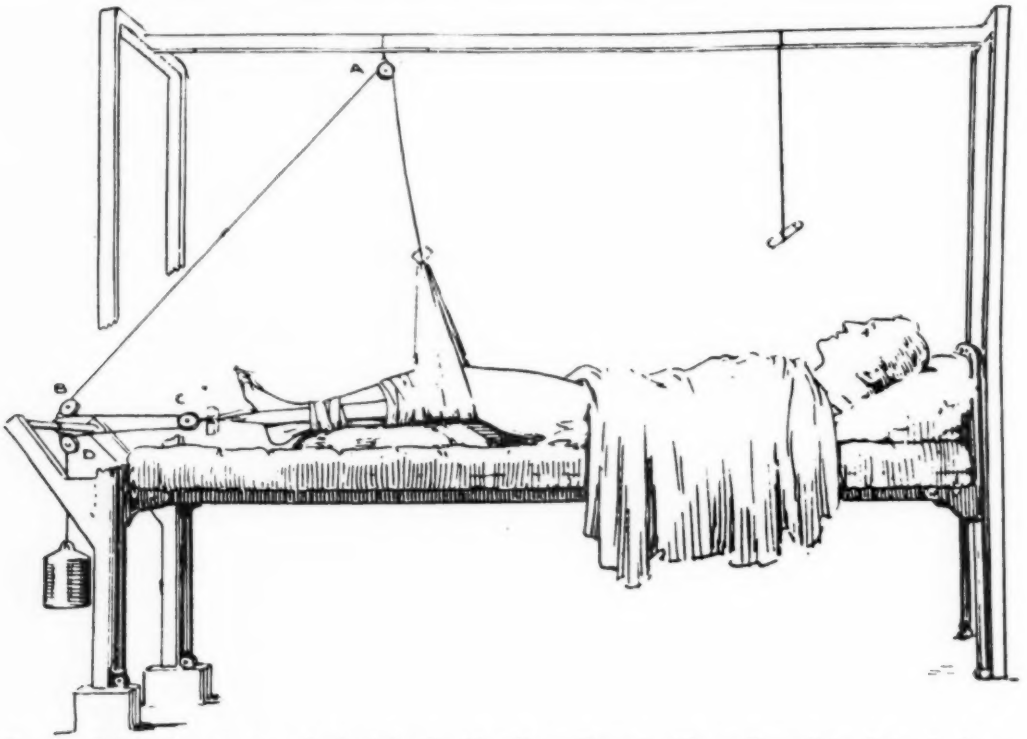


Fig. 3. Original apparatus devised by R. Hamilton Russell. (From Russell in *Brit. J. Surg.*, Vol. 2, 1924.)

article. Briefly outlined the method requires the following equipment and maneuvers:

1. A fracture bed with the foot elevated about eight inches on blocks or pins.

2. An overhead frame.

3. Moleskin adhesive strips, which are applied smoothly to the lower leg, extending from *below the head of the fibula* to just above the malleoli. The distal ends of the adhesive are attached to a spreader beyond the sole of the foot.

4. The hip is flexed to 20 degrees and abducted to about 15 degrees.

5. The knee is flexed to about 160 degrees so that the leg is parallel with the bed.

6. Soft pillows are placed beneath the calf and beneath the thigh.

7. A sling is placed beneath the well-padded popliteal space with traction applied to it obliquely via a rope to an

8. A single pulley is attached to the spreader beyond the foot, and two single pulleys are attached beyond the end of the bed on a level suitable to allow the heel to clear the bed when traction is applied.

9. The rope (preferably hatter's cord to minimize friction) is led from the knee sling to the overhead pulley, thence to one of the pulleys beyond the bed, thence back to the pulley attached to the spreader, and finally over the second pulley beyond the bed.

10. A weight of six to twelve pounds for adults, or three to six pounds for children, is attached to the end of the rope.

In utilizing this method in children no anesthesia is necessary, although in muscular adults an anesthetic during the initial phase of the traction is advisable. We have found spinal anesthesia excellent for this purpose. When the apparatus is

set up the operator stands at the foot of the bed and slowly applies traction to the leg until a force is exerted equal to the weight to be applied. The weight is then attached. Soft pillows are next applied beneath the thigh to prevent sagging of the fragments, and beneath the calf to prevent the heel from touching the bed. The result of this extension properly applied is a force directed, as shown in the diagram (Fig. 4) in the line of the shaft of the femur. It is important to make comparative measurements of the two legs, and if possible to check the position of the fragments with a fluoroscope, or by *x*-ray films, within the first six to ten hours after application of the apparatus, to determine whether too little or too much weight has been applied.

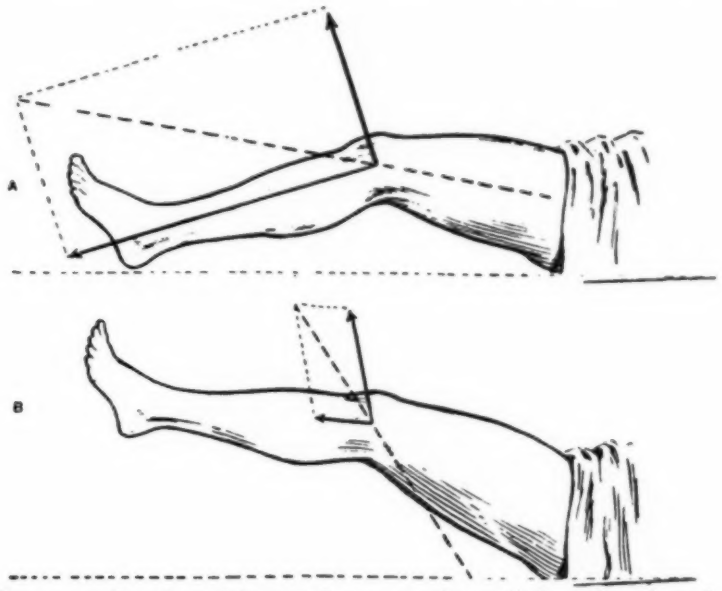


Fig. 4. A, direction of forces when correctly applied. B, direction of forces incorrectly applied. (From Russell in *Brit. J. Surg.*, Vol. 2, 1924.)

Discussion. The Russell traction method is excellent in the treatment of fractures of the intertrochanteric region. It is also good in most cases of fractures of the upper and middle thirds of the shaft, although certain modifications, such as an extra sling beneath the lower thigh to correct posterior displacement of the lower fragment, must be utilized in some cases. As a general rule this method is not efficient in treating supra-condylar fractures, but occasionally excellent results are obtained even in this region. (Figs. 5, 6, 7, 8.) Figure 7, taken from the publication of Lee and Veal, illustrates a supra-condylar fracture treated satisfactorily by the Russell apparatus.

Nursing care is greatly facilitated when the Russell method is used. Physiotherapy, such as the application of heat and light stroking massage, can be carried out without interfering with the position of the leg or the comfort of the patient. This latter consideration is perhaps the most gratifying feature of this type of traction. We are in complete agreement with Sallick and others who have emphasized the advantages of Russell traction in treating children, in the 6 to 12 year period, who are beyond the age for Bryant's traction method and in whom skeletal traction is unnecessary.

The one serious disadvantage of the Russell apparatus is that it demands frequent inspection by someone who understands the principles involved. It is unfair to expect nurses to maintain the adjustment of the apparatus unless they are mechanically minded and have been thor-

oughly instructed in the various principles of continuous traction therapy. Uncooperative or restless patients and children frequently disarrange the direction of the effective forces by shifting the position, and thereby the angle, of the popliteal sling. After the first three hours following a fracture this method is less efficient because of the rapidly increasing muscular contraction. In muscular individuals a stronger force is needed than can be obtained by skin traction unless the extension be applied before any muscle contraction occurs.

A B

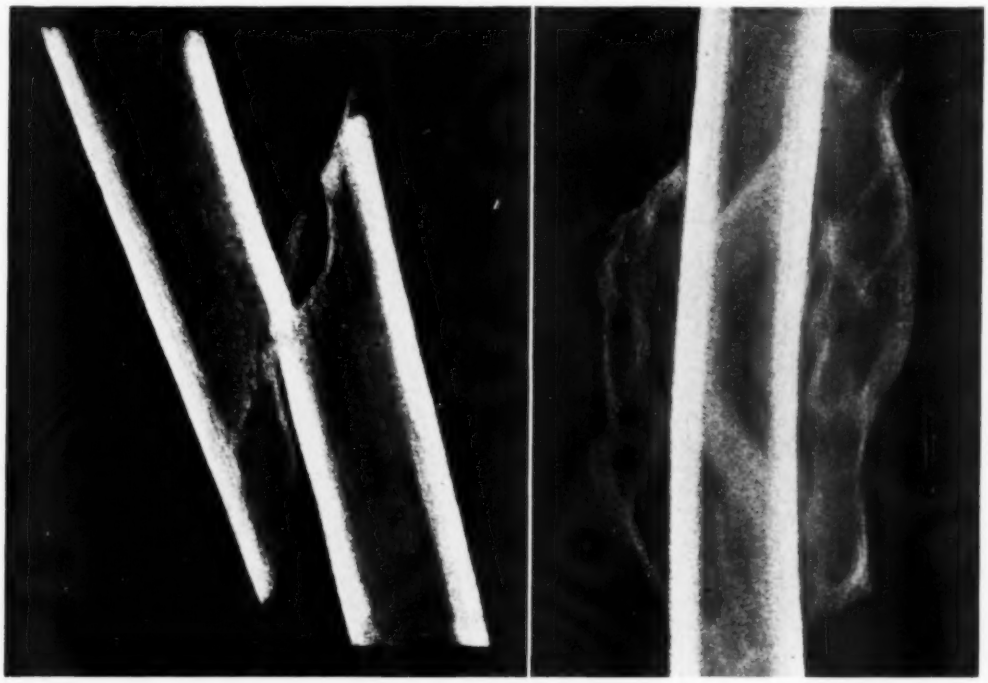
FIG. 5. A, pre-reduction *x*-ray of intertrochanteric fracture. B, *x*-ray of same fracture at time of discharge, after treatment with Russell's extension. (From Lee and Veal in *Surg., Gynec. & Obst.*, vol. 56, 1933.)

Russell's original publication advocated maintenance of traction for a period of four weeks, but it has since been shown that this time is too short for the average femoral fracture. Eight weeks is nearer the average time that we have found adequate to allow removal of the extension without recurrence of deformity. *X*-ray evidence of firm callus must be present, of course, before the discarding of apparatus is considered. One more week is then spent in bed without any sort of support, while the patient is encouraged to carry out active exercises to gain function of the hip and knee joints. Nine weeks after the injury the patient is ready to attempt walking with crutches and with a walking caliper splint on the affected leg. From that point the management is similar to the procedure outlined in other forms of treatment.

B. Adhesive Traction with Thomas Splint. An efficient form of treatment for femoral shaft fractures in children, and in adults with poorly developed musculature, may be arranged with adhesive skin traction and the use of the Thomas splint. Moleskin adhesive may be applied as two lateral bands extending from the upper third of the thigh to below the heel, or each band may be split longitudinally into three strips, the central one of which is

applied to the medial or lateral aspect of the leg, while the anterior and posterior strips are wound about the leg in a spiral manner. Elastic bandages are preferable to circular adhesive strips to bind down the long traction bands. Some surgeons prefer to split the adhesive traction, leading two bands from the thigh and two from the leg. The objection to this scheme is that the thigh strips have very little effect on the fragments, since they exert their force on the loose skin of the thigh and on the muscles and fasciae attached to the pelvis rather than on the bone involved. Having applied the moleskin adhesive, the leg is suspended in a Thomas Splint, either straight, or with a slight angle (160 degrees) at the knee, by means of slings placed to fit exactly the contours of the thigh and calf. The splint is suspended by means of ropes and pulleys so that it is perfectly balanced. Traction may then be applied over a pulley anchored at the foot of the bed. It is usually necessary to elevate the foot of the bed to increase the counter-traction afforded by the weight of the trunk and upper extremities.

Discussion. As mentioned previously, the use of this method is limited by the amount of traction which moleskin adhesive can exert without pulling away from the skin or causing excoriations. This factor can be determined by a careful consideration of the muscular development of the patient and the degree of muscular contraction which may have developed before the onset of treatment. In cases treated by plaster immobilization, or those reduced with continuous skeletal traction, it is often advisable to utilize this skin traction method for short periods after the original apparatus has been removed. Thus position and muscle balance are maintained until the healing has progressed sufficiently to allow walking in splints or with crutches.



A B

Fig. 6. A, oblique fracture of middle third of femur before reduction. B, same fracture at time of discharge from hospital, after treatment in Russell's extension apparatus. J. J., 33 years old. (From Lee and Veal in *Surg., Gynec. & Obst.*, vol. 56, 1933.)

SKELETAL TRACTION

The ideal form of traction for fractures of the femoral shaft is applied by means

of a pin, wire or calipers inserted into the distal fragment. The Kirschner wire has largely replaced the pin and calipers, both half ring modification, with a Pearson attachment to support the leg, is used. This splint is more conveniently applied

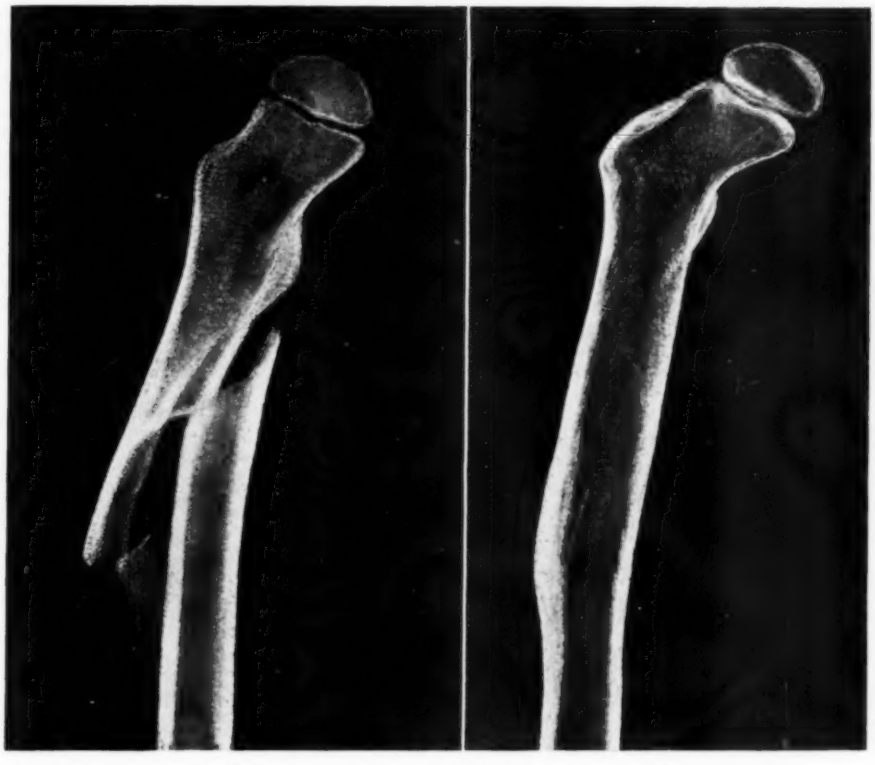
A B

FIG. 7. A, supracondylar fracture of femur before reduction. B, same fracture at time of discharge from hospital, after treatment with Russell apparatus. (From Lee and Veal in *Surg., Gynec. & Obs.*, vol. 56, 1933.)

because of the ease of insertion and the diminished danger of infection. In inserting the wire a spinal or general anesthesia is more advantageous than a local anesthesia because it permits the operator to perform a reduction at the same time by exerting traction on the wire and manipulating the lower fragment before the permanent continuous traction is applied. Detailed directions for the insertion of the wire can be found in books on surgical technique. One small point in technique which will prevent lateral slipping of the wire in the bone, and the possible infection incident thereto, consists of threading corks on both ends of the wire and pushing them snugly against the skin dressings. Then the arms of the yoke are pressed closely against the outer surfaces of the corks, so that there can be no play between the yoke and the skin.

In setting up a skeletal traction apparatus, the fracture bed and Balkan frame are essential. A Thomas splint, preferably the before the Kirschner wire is inserted. After the wire is in place a system of balanced suspension is utilized to elevate the splint. The thigh is usually fixed most advantageously at about 45 degree flexion, the leg being parallel with the bed. Buckles or slings may be used to fix the Pearson attachment securely to the Thomas splint. The slings of Canton flannel or toweling which support the leg on the splint must be carefully applied and well padded, especially in the popliteal space. The line of traction on the Kirschner wire must always be parallel with the line of the Thomas splint. In order to utilize the full efficiency of this method it is essential to apply the maximum weight (often 20 pounds or more) required to overcome shortening at the time of the original set-up. If this is not done, it becomes increasingly difficult to overcome the progressive muscle contraction by subsequent additions of weight, and the total weight then required is considerably greater than

would have been necessary to effect reduction at the start. Measurements and *x*-ray or fluoroscopic check-ups are required to carefully balanced by a cord running from the distal end of the splint to an overhead pulley, and thence towards the head of the



A B

Fig. 8. A, spiral comminuted fracture of upper third of shaft of femur before extension was applied. B, same fracture at time of discharge from hospital, after treatment in Russell extension apparatus. R., aged 5 years. (From Lee and Veal in *Surg., Gynec. & Obst.*, vol. 56, 1933.)

determine the status of the length of the bone at frequent intervals during the first twenty-four hours. It is also important to continue this check of the length of the limb at regular intervals of forty-eight to seventy-two hours until firm callus has formed, in order to guard against overpull and separation of the fragments. One of the many schemes for prevention of foot-drop should be utilized in this as in other prolonged traction arrangements.

After there is definite evidence of firm healing clinically and by *x*-ray examination the leg is mobilized, by removing the buckles or slings which held the two splints together, thus permitting the hinge joint at the knee level to function. This will usually be safe at the end of four to five weeks. The Pearson splint and the leg are bed over another pulley with a long piece of rope, to which an adequate weight is attached. This scheme allows the patient to initiate motions of the knee slowly and passively within pain limits by pulling and releasing the weighted rope. Gradually active motions of the balanced splint become possible without the use of the hand rope. It is practicable and advisable to use the wire traction until firm union has occurred. This usually requires eight to ten weeks. At the end of that time the wire is removed and the patient allowed to lie in the balanced splints without traction for several days, while continuing active exercises. Then a non-weight-bearing walking caliper splint is obtained and walking with crutches instituted. One or both crutches are discarded at varying times

depending upon the agility of the individual. As a rule, the walking splint may be discarded four to five months after the original injury. (Fig. 9.)

Discussion. The superiority of this method of treating fractures of the shaft of the femur in young adults cannot be too strongly emphasized. The comfort to the patient and the accessibility of the thigh for nursing and physio-therapeutic procedures have been mentioned previously but deserve repetition. Lateral or rotary deformities may be corrected with facility in many cases by the addition of Canton flannel slings, passed around the thigh, through which lateral traction may be exerted by pulling on the limbs of the splint.

The danger of an osteomyelitis at the site of the wire wound is the only important disadvantage of skeletal traction. Actually this is not a serious hazard if ordinary care is exercised in the insertion of the wire. We have never seen a bone infection as the result of the wire wound.

Hodgen Splint. We have had no personal experience with the use of the Hodgen splint in the treatment of fractures of the femur. Excellent results have been obtained by its use, but it requires special knowledge in order to arrange and maintain the forces and angles in the proper manner. The other methods considered seem simpler and equally efficacious.

Hoke Traction Apparatus. This method combines traction and plaster fixation. Adhesive plaster strips are applied to the lateral and medial surfaces of the fractured leg. A double plaster of Paris spica is then applied with the patient on the fracture table. This plaster should extend from the umbilicus down to and including the foot, the sole of which is well padded, on the extended sound leg, and down to the lower third of the leg on the side of the fracture. The Hoke apparatus is then incorporated in the lower end of the plaster on the affected side, and the adhesive traction strips attached. After the plaster has set, the position of the fragments is discovered by *x*-ray examination, and then suitable traction is applied to obtain the required length.

This method is especially adapted to the treatment of long spiral fractures which may require lateral support as well as traction. It allows transportation of the patient without disturbing the position of fragments. For this reason it is advantageous in treating some elderly patients, who require frequent turning and change of position in bed, in order to prevent the occurrence of bed sores and to stimulate the circulation. In these latter cases the prolonged pressure of the plaster casing on relatively poorly vascularized skin and soft tissues is not well borne. After six to eight weeks in this apparatus, the plaster should be bivalved to determine the degree of healing. The subsequent treatment is similar to that described in the use of immediate reduction and application of plaster.

AMBULATORY METHODS

During the past few years several ambulatory methods for treating fractures of the femur have been described. Roger Anderson is a staunch advocate of this procedure. His recently described technique[1] involves the insertion of two pins into the upper fragment, one through the greater trochanter and one through the shaft, and two pins through the lower fragment just above the condyles. The pins are inserted from the lateral aspect and penetrate the entire thickness of the bone. Special yokes and brackets, on a specially designed splint frame, hold the pins so that the reduced position is maintained after traction and manipulation. A plaster casing, extending from the groin to the knee is then applied, incorporating the four pins and thus preventing recurrence of the deformity.

Another ambulatory method has been presented recently by R. A. Griswold.[10] He utilizes two pins in the bone, one placed in an anteroposterior direction just below the greater trochanter, and the second in a lateral direction just above the

A B

C

FIG. 9. Patient, F. G. A, fracture of shaft of femur, middle third, on admission. B, same fracture after application of Kirschner wire traction and reduction. Skeletal traction maintained for seven and one-half weeks. C, position and healing at time of discharge. Note adequate callus, and partial loss of alignment in lateral view. Patient walked with crutches, but without splints, eighty days after his accident.

adductor tubercle. Reduction is accomplished on a fracture table, and a non-padded walking spica of plaster of Paris is applied, extending from the costal margin to the toes on the affected side. This method afforded good results in ten cases.

Discussion. Several distinct advantages are apparent at once in the use of these or similar ambulatory methods of fixation. In fractures which would be difficult to hold reduced by the simple traction methods, or by fixation in plaster, the points of skeletal fixation afforded by the pins (when incorporated in plaster) serve to hold the position quite rigidly. As soon as the plaster has dried thoroughly, the patient is encouraged to walk with the aid of crutches. Gradually, as confidence is gained, the crutches may be discarded. The shortened time of hospitalization has obvious economic advantages. By the Anderson method, with plaster covering the thigh only, knee and hip motions are preserved from the start of treatment. There may be some value in the slight pounding of the fractured surfaces, incident to walking, which may stimulate healing in certain cases, which would otherwise go on to delayed or non-union.

Despite these advantages of the ambulatory methods of treatment we are somewhat reluctant to recommend them for general use. The number of cases treated in this manner is too small at this time to permit a just evaluation of the end-results. Furthermore, such procedures require specialized instruments, apparatus and technical skill which are elements difficult to combine at the present time in the organization of the average surgical service. Open reduction with internal fixation would seem to be a more desirable method of dealing with those fractures which cannot be held by the ordinary methods of closed reduction.

FRACTURES IN CHILDREN

Fractures of the shaft of the femur in children present deformities and malformations similar to those noted in adults. In addition, one occasionally encounters a subperiosteal fracture in a child without displacement of fragments. Because of the weaker and more elastic muscles, reduction and fixation are less difficult than in adults. The prognosis in children is almost invariably good, as a result of the remarkable corrections of disalignment, angulation and shortening which nature accomplishes.

In infants a satisfactory method of fixation is that described by Van Arsdale.[22] After satisfactory reduction has been achieved a specially designed equilateral triangular cardboard splint is applied. One leg of the triangle is bound about the trunk and the second leg is bound about the acutely flexed thigh with an apex in the inguinal fold. The third leg joins the other two and serves to hold the thigh in the flexed position. This arrangement is efficient, not uncomfortable and greatly facilitates nursing procedures.

Fractures in children between infancy and 12 years of age often can be treated satisfactorily by immediate reduction and immobilization in a plaster of Paris spica. Flexion of the hip and knee may approach 90 degrees because of the perfect muscular relaxation present in these young patients. With lesser degrees of flexion the fragments occasionally slip out of position. The frequent soiling of the plaster by excreta is a decided disadvantage of this method.

Bryant's extension apparatus is the method of choice in children up to the age of 6 years. In this procedure adhesive skin traction is applied to both legs extending from mid-thighs to spreaders beyond the feet. From the spreaders, ropes lead vertically upwards over pulleys suspended from an overhead frame. Weights just heavy enough to life the buttocks and lower portion of the back from the bed are attached to the ropes. In some cases it is necessary to apply restraining sheets across the lower abdomen, or better, some specially designed retractor, such as that described by Conwell.[6]

Older children may be treated in a manner similar to that described for adults. Skin traction is utilized more frequently than in adults since the weaker muscles do not require as great a traction force. When abrasions or other skin injuries make the use of skin traction impractical, skeletal traction should be used without hesitation, provided one avoids the epiphyses with the wire or pin.

PHYSIO-THERAPY

Today any discussion of fracture treatment is not complete without at least a cursory consideration of the role of physiotherapy in the healing process. The attainment of normal anatomical and physiological states always has been the aim of those interested in fracture treatment. Recently under the influence of the Workmen's Compensation laws and the numerous special clinics established by industrial plants, the treatment of traumatic injuries has been considered more particularly from its economic aspect. The disability time is now held as of equal importance with the anatomical and functional results in determining the excellence of the end-result in any given fracture. It is in the solution of the problem of rehabilitation that the assistance of physio-therapy is valuable.

Physio-therapy is efficacious in three definite stages of the treatment of a fracture. The time when its application is most valuable—and strangely enough this is the time when it is most often neglected—is the period immediately following the injury. In the first minutes or hours after injury, while awaiting the preparations for reduction, properly executed light stroking massage of the injured part will prevent to a large extent the development of muscle spasm as well as the spasm of blood and lymphatic vessels. Swelling is thereby diminished, reduction is facilitated, and the analgesic effect on the patient is remarkable. After reduction and immobilization similar light massage, together with elevation and constant heat of low intensity, will promote further the relaxation of muscles and vessels. Thus hemorrhage and inflammatory exudate are removed before extensive infiltration of soft parts and organization into scar tissue occur. Guided active motions of the injured part within pain limits, if such activity does not endanger the maintenance of reduction, provides a third means of stimulating the circulation of the affected area.

The second stage of physio-therapy begins after reduction has been accomplished and lasts throughout the period of bone healing, while the limb is fixed in splints or apparatus. The problem during this period becomes one of regaining or maintaining functional activity of the muscles and joints of the affected part. Guided active motion, when the type of fracture and apparatus permit, is the preferable form of physio-therapy. However, muscle stimulation by appropriate electrical currents is excellent for maintaining muscle tone. In cases treated by immobilization in plaster, exercises in voluntary muscle contraction, faithfully carried out, will greatly improve the circulation of the soft parts and prevent the muscle atrophy which so often accompanies that form of treatment. Elevation of the limb and the application of continuous heat should be carried out throughout this period.

The third stage of treatment is the so-called "after treatment," beginning when bone healing has advanced sufficiently to allow discarding splints or apparatus. It is in this phase that physio-therapy finds its greatest use in treating the stiffness and atrophy following prolonged immobilization. If physio-therapy is used intelligently during the first two stages of fracture treatment, the necessity for the prolonged third stage would be eliminated to a large degree. Numerous types of heating devices and electrical apparatus for the restoration of function and prevention of atrophy are in common use, while only too often the essential feature of

treatment at this stage of the injury is neglected. The latter consists quite simply in the active use of the part by the patient. Whether the activity is prescribed as formal exercises, or more subtly as occupational therapy, matters little. The fact remains that function will return as soon as muscular activity is resumed, and if this activity is postponed in favor of a course of heat, massage and electrical treatments the convalescence of the patient will be unnecessarily prolonged.

The importance of utilizing the various simple therapeutic measures above outlined in fractures of the femur cannot be overemphasized. Atrophy of the thigh muscles is notoriously common and extreme following even minor leg injuries which necessitate disuse for periods of time as short as ten days. The diminished disability time following the preservation of muscle tone and joint function during the time of bone healing has been convincingly proved by comparisons of series of cases with and without the benefits of suitable physiotherapeutic treatment. For the most convenient exhibition of physio-therapy in femoral fractures, a traction-suspension apparatus is ideal. By utilizing skeletal traction rather than adhesive skin traction the accessibility of the leg for heat, massage and electrical stimulation of muscles is further increased, and motions of the knee joint may be initiated at an earlier date.

RATING OF RESULTS

In order to judge accurately the results obtained in the treatment of fractures it is necessary to follow the patients over periods of years, rather than months, and to rate the results according to a definite plan. This is especially valuable in evaluating the end-results of femoral fractures because even the cases which have responded best to treatment frequently have minor deformities and disabilities for one, two, or more, years after discharge from the care of a surgeon. The most satisfactory and commonly used system of rating considers separately the anatomical, physiological and economical states of the affected part. In estimations of the anatomical restoration we use the method suggested by Lee and Veal in 1933. Perfect alignment is rated 50 per cent, end-to-end apposition 25 per cent, and overlapping demands a deduction of 25 per cent. This estimate is based entirely upon the appearance of the lesion in *x*-ray films. In many clinics, separate anatomical ratings are given for clinical and *x*-ray results. The physiological rating depends upon restoration of function of the affected part, together with the evaluation of symptoms resulting from the fracture. The degree to which the patient is able to resume his previous activity or occupation determines the economic rating. Unsettled law suits or the receipt of generous stipends from compensation funds frequently exert unfavorable influences, from the surgeon's point of view, upon the excellence of the economic result.

In addition to the establishment of a definite system of rating it is desirable, in hospitals treating many fractures, to have a special fracture organization of the staff to which the rating as well as the treatment of fractures may be entrusted. The Follow-up Clinics built up by fracture groups in several of the larger eastern hospitals have been responsible for many advances in treatment. It is only by following cases for several years after discharge from active treatment that one is able to evaluate fairly the efficacy of any given form of treatment.

SUMMARY

1. The necessity for considering fractures of the shaft of the femur as major surgical emergencies is stressed, with special reference to the treatment of elderly patients and children.

2. The anatomy of the femur and its attached muscles is considered briefly and the typical deformities of fractures at varying levels outlined.

3. The essential factors in establishing the diagnosis of a fracture of the shaft of the femur are enumerated.

4. Adequate emergency treatment for the fresh femoral fracture is emphasized and a plea made for the education of laymen regarding such treatment.

5. The two major principles of treatment of fractures of the femur are:

a. Immediate reduction and fixation in plaster.

b. Reduction by means of continuous traction applied to either the skin or the skeleton.

6. Campbell's method for immediate reduction and fixation in plaster is recommended.

7. Continuous traction methods are more generally utilized since they require less specialized skill in application. The techniques of the Russell extension apparatus and of traction-suspension in a Thomas splint with skin and skeletal traction are briefly described.

8. Despite the definite advantages of ambulatory methods of treatment the relatively complicated apparatus and techniques required, as well as the limited number of cases so treated, cause reluctance to recommend such methods for general use.

9. Bryant's extension apparatus is ideal for children under six years of age. Above that age skin adhesive traction with a Thomas splint, or the Russell apparatus, is the method of choice.

10. The importance of physio-therapy, especially in the early stages of fracture treatment, is emphasized. Constant heat of low intensity, light stroking massage and guided active motion are suggested as the best forms of physio-therapy.

11. Rating the results of femoral fractures according to anatomical, physiological and economic criteria, together with a follow-up system extending beyond the period of treatment, will permit a more accurate determination of the end-results and efficiency of various forms of treatment.

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THE OPERATIVE TREATMENT OF FRACTURES OF THE SHAFT OF THE FEMUR

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THE operative treatment for fracture of the femur is now an established procedure. The technique involved is that based on the fundamental principles as laid down by Lane, and augmented by Sherman and others. It has, as have all other methods of treatment, limitations whose boundaries are broader for the surgeon of wider experience and ability and likewise more limited to the surgeon of lesser experience and training, and certainly is not a procedure to be undertaken by the neophyte or the too ambitious.

An important factor that one must keep in mind, once the decision for open reduction is made, is the selection of the proper time for it. It is needless to say that any trauma so severe as to cause a fracture of the largest long bone in the body must produce great soft tissue damage, with the attendant hemorrhage and shock. It is our experience that as a rule, one must wait for at least a week or, better, nine days after the injury before operating. During this time the host has overcome the nervous shock, and the process of repair is well organized, as noted by normal temperature, pulse and respiration. In the tissues the large and small vessels are well clotted with organization of the original hemorrhage beginning, etc. As stated before, this happens during the first seven days, and one or two days after this, one must consider the time optimum.

During this time the patient has had opportunity to become acquainted with his new surroundings, he has made new friends, learned that they have had operations of a similar nature and are recovering; he has gained confidence in the nursing staff, learned the use of utensils for nature's calls and in general has become what might be best expressed as "hospital broken."

The ideal type of fracture of the femur that lends itself to the operative procedure is the transverse fracture of the middle third. It is here, not only because of the usual shortening that follows this type, but because, as we know, by the various closed and semi-closed methods, one cannot be sure of obtaining end-to-end approximation of one-third to one-half the diameter of the fractured surface of the shaft with normal alignment. Whereas by the open method, because of the ready approach, the reduction with normal anatomical reposition of the parts can be accomplished. The oblique and slightly comminuted types of fracture of the middle third of the shaft can be included in this group. As one approaches either the upper third or lower third of the shaft, these types (i.e. transverse, oblique, or slightly comminuted) are often to be included in the operable field, but the procedure is of a greater note and complete reduction harder to secure. In this group, one could include any fracture of these types extending from below the level of the lesser trochanter to the so-called supra-condylar region. The intra-trochanteric, multiple comminuted, long oblique, spiral, etc., in which there is relatively little shortening that can be corrected by skeletal traction, and often do not offer sufficient bone to permit internal fixation, are not to be included in the list.

The best method of internal fixation that has been devised to date is by the use of the Sherman tap screw and bone plate. Both the plate and the screw are modeled on sound mechanical principles. The plate is made of Vanadium steel, an alloy that has a minimum of carbon, which gives it toughness and permits bending and twisting under great stress before breaking. The screws are of the same material and

are a combination of a machine tap and screw with the point fluted to permit escape of the tapped out bone debris from the threads. The head of the screw is machine cut with the under surface tapered, so that it fits snugly in the countersink in the plate. These have been minutely described in an article by Sherman in *Surgery, Gynecology & Obstetrics*, June, 1912, pages 629–634, showing the mechanical principles involved and with comparisons of other materials.

The preparation of the patient is a matter of choice. We feel that the mental attitude of the patient is a factor to be considered, and for that reason we usually show him the *x*-ray films and explain our contemplated procedure. It is interesting to note the ready conception or understanding of the method the average individual has and the good effects that it has on his morale, by taking the patient into one's confidence and consideration during the discussion. In this way the medico-legal aspects are covered and often prevent postoperative criticisms and complications.

The anesthetic again is a matter of choice and taken by and large, we feel that spinal anesthesia is the best. According to the type of fracture and the estimated length of time necessary for the operative procedure, we use either the 100 mmgs. or 120 mmgs. neocaine dose. This is placed as low as possible in the subarachnoid space and without ballotment of the syringe, it giving 40 to 120 minutes of analgesia and complete muscular relaxation. Occasionally, because of preconceived ideas or on the advice of friends, one meets the patient who protests against spinal anesthesia and wants to be asleep. His physical condition permitting, we then comply. A general anesthesia of ethylen-ether is then given and more recently we have enjoyed working with the patient under Pentothal. This latter drug gives excellent muscular relaxation and has less mental and respiratory effect and disturbance, respectively.

The preparation of the part is a simple one—no over-night applications are necessary. At the time of operation, the part having been previously shaved, if the skin is of a hairy nature, and this by the dry method, the part is cleansed first with ether, then with alcohol and then ether again, to remove the débris, fat, etc. At the site of exposure or completely around the thigh, one applies a 5 per cent alcoholic solution of picric acid, while traction on the femur through the tibia is being made by an assistant, to prevent greater deformity and trauma. The sterile field is now secured by the surgeon or his assistant with wrapping of the distal part of the leg to permit later traction and manipulation without contaminating the field. In this manner, if properly done, no part of the unprepared field is exposed. The area of incision is protected by blocking the field with a Bacchus clamp at each angle of the rectangular area. At this point a second application of picric acid solution is made. To give a better presentation of the part, a folded sheet placed beneath the thigh, from the level of the trochanter to the knee is often useful.

Aside from the qualifications of the surgeon, one should have the necessary instruments or armamentarium. In our clinic we hold as a minimum, the following:

First Tray

1 Scalpel,
1 pr. Scissors (straight),
1 Tissue Forceps,
1 doz. Hemostats,
2 Michele clips forceps,
6 Bacchus clamps,
Either 2 doz. Moynihan clamps or large Michel clips,
Catgut plain #1

Second Tray

1 Scalpel,
1 pr. Scissors (straight),
1 pr. Scissors (curved—large),
1 Tissue forceps,
1 doz. Oschner hemostats,
1 doz. Hemostats (curved),
½ doz. Hemostats (straight),
Retractors (modified Deever),
Periosteal elevator,
Curettes (3 different sizes),
2 Needle Holders,
Needles for muscle & fascia with #1 chromic catgut—double,

2 Skin needles with black linen or Michel clips with forceps for skin incision,
Bone cutters { curved / straight
Rongeurs,
Chisels 3 assorted sizes,
Mallet,
2 Lane clamps,
2 Lambotte clamps,
Berg clamps 3 sizes,
1 Lowman clamp,
1 Femur clamp (modified),
2 Smith-Petersen clamps,
Caliper,
Hudson elevator,
Lane elevator,
Bone skid,
Sequestrum forceps,
1 Bone drill with 3 #32 Brown-Sharp bits,
3 Screw Drivers,
Sherman-Vanadium steel bone plates sizes 1, 2, 3, 4 with assorted screws from ½"–1¾" length,
Instrument carriers,
Nurses clamps.

Along with this armamentarium, one should consider his assistants, of which there should be at least three: one to retract the muscles, the other to aid in the operative procedure itself, and the third to make traction and manipulation of the part as desired. These men should be thoroughly trained in the Lane method, or the so-called non-hand contact technique. No instrument, gauze or catgut which comes in contact with the deep tissues should in any way be touched by the operator or his assistants, except by the use of forceps, meaning that the gauze should be opened and handled with instruments by the nurse and first assistant; the catgut and needles should be threaded in the same manner. Sponging is done by instruments alone. The sponges should be of the large variety and a count kept of them, as one does with the instruments.

The type of incision is again a matter of choice. In the middle third of the thigh we prefer the muscle splitting incision of Henry, described in the *British Medical Journal*, 1934, page 84. The line of incision follows a line drawn from the anterior superior spine in a direction to the lateral side of the patella. This, after incision of the deep fascia, permits a muscle splitting of the rectus femoris and vastus externus, which when retracted presents the crureus and this is the only muscle necessitating incision. This is not always so, because the trauma affected by the fractured ends of the bones might have caused enough rupture so that retraction alone is sufficient. Exposure through the lateral incision in which the fascia lata, vastus externus and portion of the crureus are incised, is the second choice. However, as one approaches either the lower or upper extremities of the shaft, this incision is, I feel, the better one. The Henry incision can be readily prolonged, however, to be used for either exposure.

TECHNIQUE OF OPERATION

With the patient in the proper position flat on the table with thighs extended. thoroughly anesthetized, sterile fields prepared, with the application of picric acid, an assistant makes slight traction on the lower fragment by firmly grasping the sterile draped leg. The incision of choice, usually 8 or 12 inches in length giving necessary exposure is made through the skin and subcutaneous fat down to the deep fascia, with slight undermining of the superficial soft parts. The bleeding points are caught with straight clamps, so that the field is perfectly dry. Any sponging at this time is done by the assistant. Thorough hemastasis or ligation of the bleeding points with single #1 plain catgut is carried out, using the two hemostat method to tie. After completely ligating all the vessels, the field is thoroughly blocked with towels, using either the prepared Turkish toweling or the ordinary linen towel. This is applied to the incised area so that the towel edge over-laps the skin edge with no skin edge showing and is fixed in this position either by the use of large Michel clips, placed approximately 1 inch apart, or by the use of Moynihan or Lane towel clamps. These latter are more cumbersome. After thorough blocking of the skin edges, the towels are clamped at the angles of the wound by the use of a Bacchus clamp. All instruments used up to this point are placed on the

first tray and discarded for any further use. This procedure should have been done in an almost bloodless manner, so that the only blood stain present is that possibly due to oozing from the skin edges through the toweling. The operator and assistants, as a matter of procedure and precaution, wash their hands first through Dakin's solution, which acts not only as a hemolytic agent and dissolves any blood that might have come in contact with the fingers, but as an antiseptic. This is done because one might have unconsciously touched the skin with the hands in proceeding to this point. The sodium hypochlorite solution is removed by rinsing of the gloved hands in sterile water.

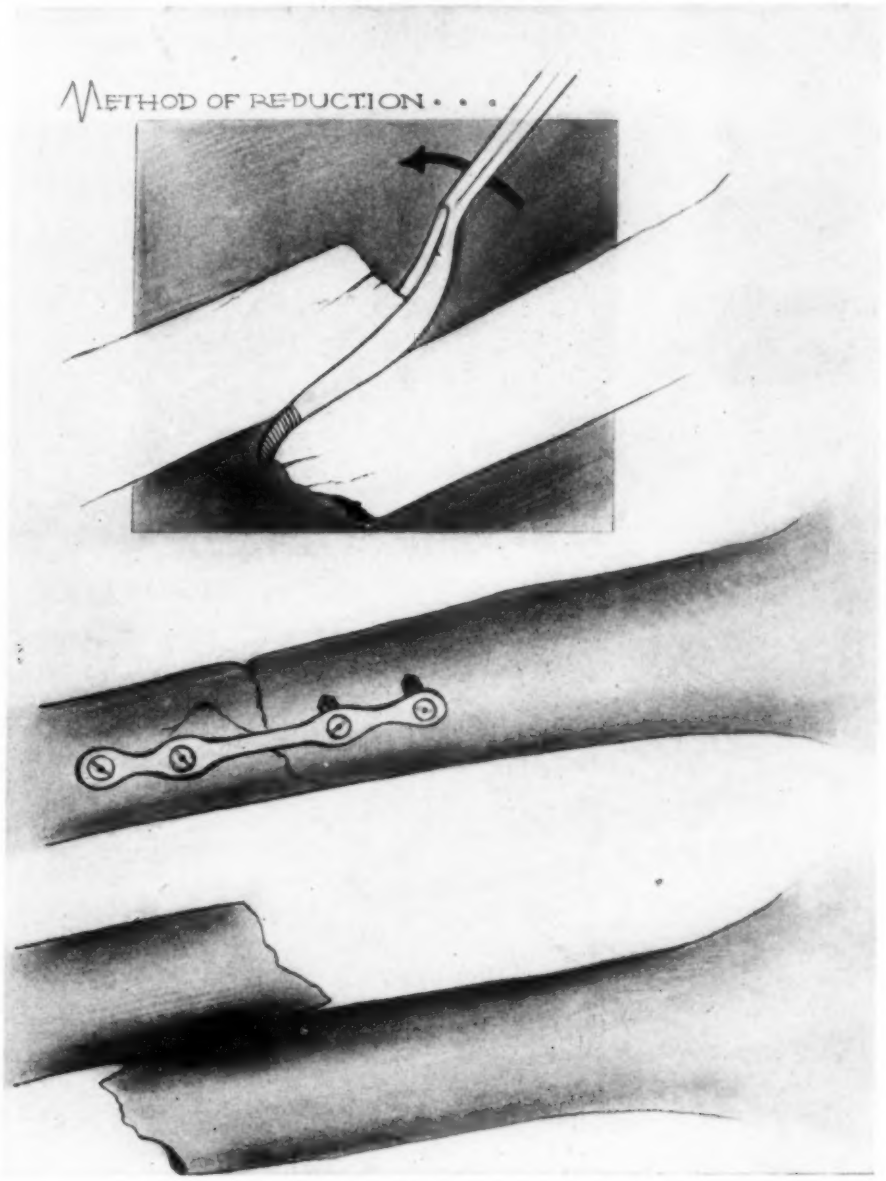

Fig. 1.

With clean, fresh instruments, the fractured ends of the bone are now exposed. If by the muscle splitting incision of Henry, the deep fascia is incised in a direction of the original incision, directly beneath this lies the cleavage of the vastus externus and rectus femoris. By the use of the curved Hudson separator or curved scissors, these muscles are readily separated, one or two small arteries might of necessity be clamped. At the upper angle of this incision

one encounters an oblique neuro-muscular bundle, which consists of the descending branches of the external circumflex artery, and the rectus femoris, the shining crureus comes into ready view. According to the degree of force and its directness, the cru-

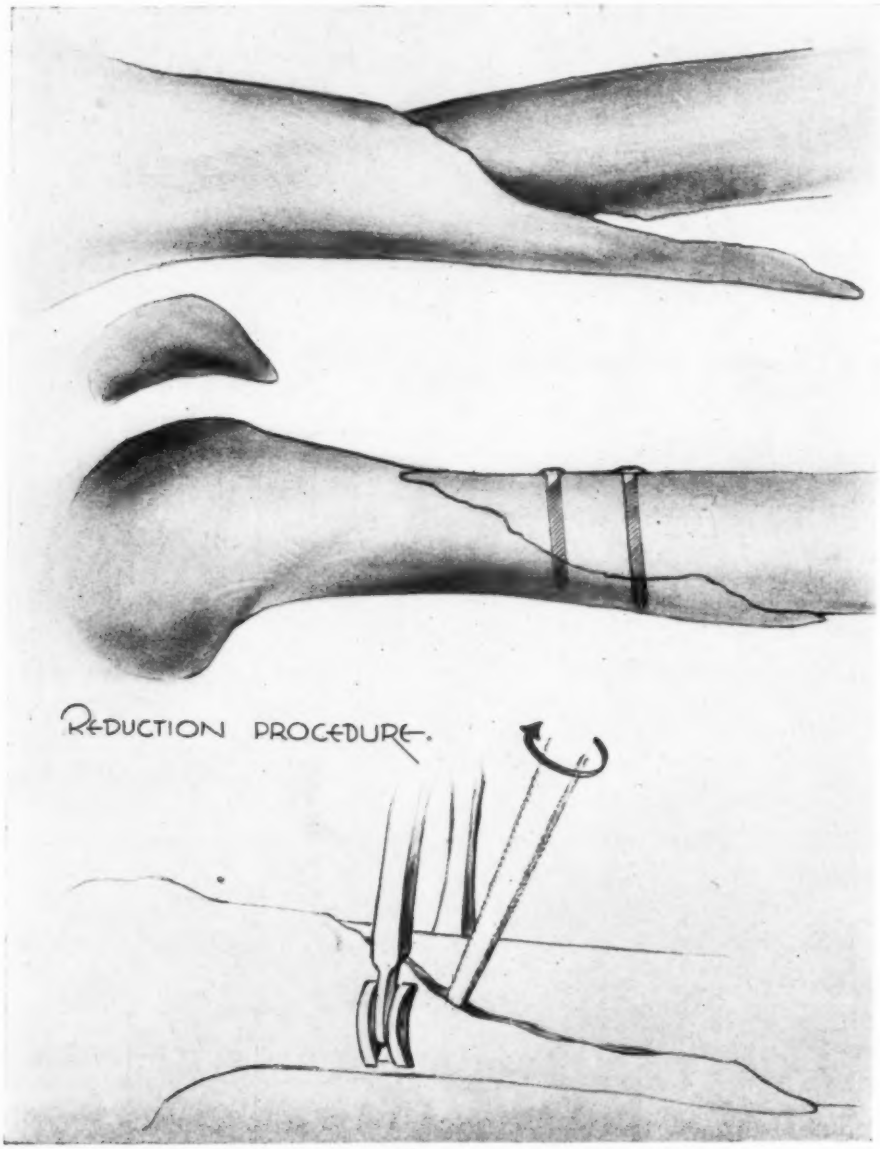

Fig. 2.

its companion vein, and the nerves to the vastus externus. This can be easily protected when once recognized and does not necessitate clamping or incision, but can be readily retracted as desired. If the incision is of a lateral type, after incising the fascia lata, a sharp incision through the vastus externus must be made. Here one encounters the three perforating branches of the femoral profunda artery which must be separately caught and clamped. With proper retraction of the vastus externus reus may be torn for a varying extent, sometimes completely with partial rupture of the overlying muscles, making the approach to the bone rather easy. By longitudinal incision in the periosteum with lateral separation of the muscle fibers down to the bone, the upper and lower fragments are readily exposed. Liquefied blood clot and interposed muscle fragments with organized clot will be found at the site of fracture. By use of the large curette and sponging, not rubbing, this material should

be removed and thorough hemastasis effected. At this point with the use of appropriate bone clamps, either the Lambotte, Lane, Berg, or others, the upper and lower fragments are separately grasped. In the transverse fracture the upper and lower fragments are slightly angulated, so as to give a complete exposure to the fractured surfaces. The fractured ends are thoroughly curetted to remove the organized blood clot. The fractured surface of the bones are then placed end to end and by bringing the lower fragment into normal alignment with the upper, the shortening is corrected. The reduction can also be produced by the use of the Murphy bone skid, using the upper fragment as the fixed point or fulcrum of the lever. (Fig. 1.) In case of the spiral or oblique type of fracture, the shortening can be overcome and normal apposition can be accomplished by traction and counter-traction and approximating the fractured surfaces with a Lambotte clamp. A Lane bone extension clamp is then inserted between the raw surfaces and by rotation, the parts are moulded or jockeyed into position. (Fig. 2.)

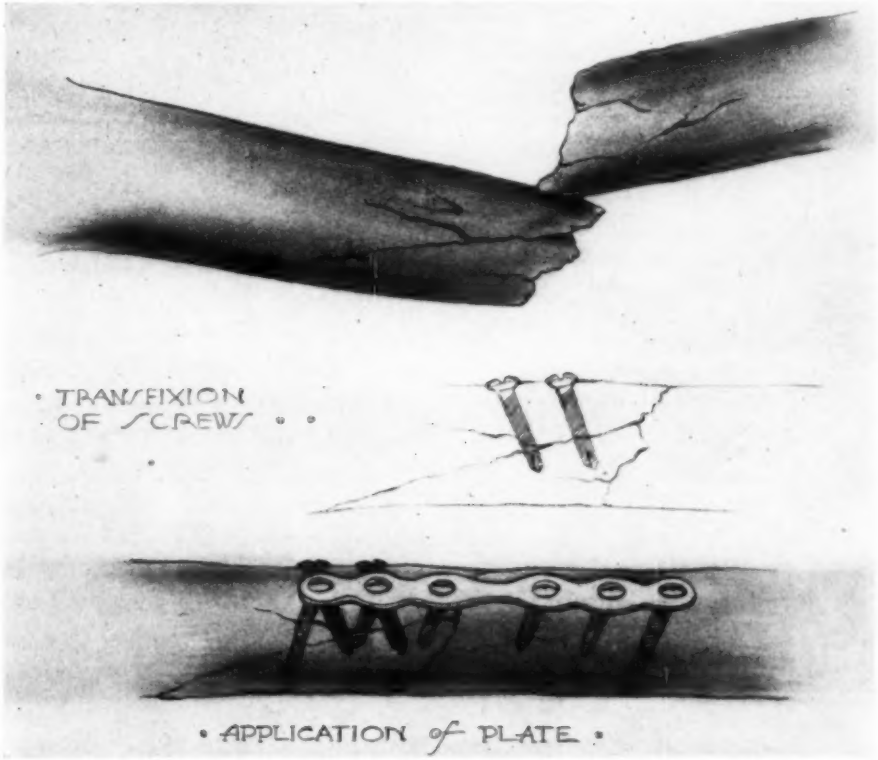

Fig. 3.

In the comminuted types with one or two fragments, the large fragments are fitted to the normal position, either to the upper or lower fragments, fixed by plate or screw and then the reduced part treated as a separate fragment. At this point, either by the eye or by actual caliper measurement, the diameter of the femur is ascertained and a suitable Sherman bone plate is applied, using the six screw plate—the heavier the plate the better. If the patient is a large individual and the type of fracture turns from the transverse to the oblique, the six screw plate is best. However, if there is a simple transverse fracture which is readily approximated and seems to remain in the position of reduction of its own accord, showing a certain amount of fixation by muscular action and splinting, then the four screw plate suffices. The plate is applied so that the points of fixation (screws) are equally distributed

above and below the site of fracture and usually is placed parallel with the long axis of the bone. The plate is applied on

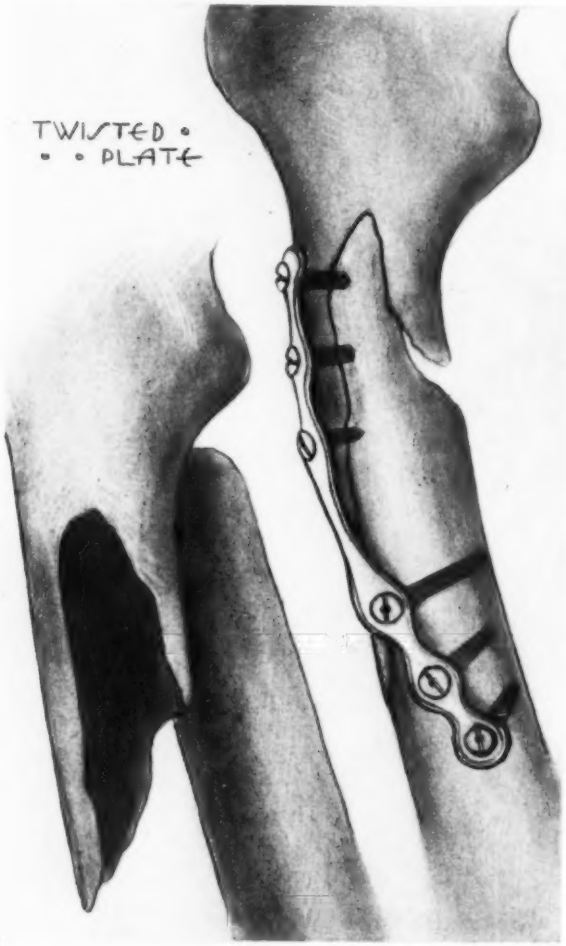

Fig. 4.

the lateral position or an antero-lateral aspect and should lie beneath the periosteum. It is best fixed in position prior to drilling of the bone by the use of either a Lambotte or a Lowman clamp. At times, because of the lines of fracture, to secure proper fixation the plate must be angulated to conform to the angle of the femur, or twisted on its long axis. (Figs. 3 and 4.) By the use of No. 32 Brown Sharp drill, the bone is drilled at right angles to the plate and according to the amount of fixation required, the bit penetrates the proximal cortex for short screws, and for transfixation screws the distal cortex. It is our custom to use at least one transfixation screw in the upper and lower half of the plate. (Fig. 3.) To prevent embarrassment, the screws should be inspected to make sure the flute is not flanged—for if so, the hole is simply made longer, the screw acting as a reamer without purchase, rather than tapped. (See Sherman's article.) If the reduction is firm, one can fix the plate by placing the screws alternately on each side of the fracture. On the other hand, if the bone is apt to slip, which is sometimes the case, it is best to fix the bone plate completely either to the upper or lower fragment with one, two or three screws and then if necessary the readjustment and normal alignment is ofttimes easily affected by the addition of the plate with the necessary fixation after the proper reposition. If the fracture line is an oblique or spiral one and normal approximation has been secured, then fixation is readily obtained by drilling through both or opposite cortices and by the use of two or more long fixation screws. (Fig. 2.) In the comminuted fractures, ofttimes the larger bone fragments can be used as bone plates and fixation to the upper and lower fragments by transfixation screws suffices. At this point, testing of the fixation and plate should be done by moving the part from side to side, together with flexion of the knee at a right angle. By the latter maneuver, any intermuscular and peri-articular adhesions are readily separated. Hoping that the bone fragments will remain in perfect position and there is no defect in the plate or screws, as such a strain and stress would readily show the same, one prepares to close the wound. A final inspection of the wound for hermorrhage, sponges and instruments should be made. The rent in the crureus is closed by interrupted double chromic catgut No. 1. The wound is again inspected to make sure of hemastasis, the over-lying muscles closed with a single chromic catgut suture No. 1; the deep fascia (fascia lata) sutured with continuous double chromic catgut No. 1, ever second or third stitch being interlocked. The skin is closed with vertical mattress sutures of black silk or Michel clips. Drainage is never indicated

in simple fractures, as we feel it leads to, rather than away from, infection. A simple gauze dressing is applied to the wound.

POST-OPERATIVE SPLINTING

As a routine procedure a half ring Thomas, to which has been applied a Pearson attachment with the knee joint flexed to approximately 45 degrees should be applied. The thigh is held in position in the splint by the application of adhesive plaster to the internal and external aspects of the thigh with a minimum of traction through a Spanish windlass, and the femur fixed in the splint with a circular cotton bandage. The leg should be bandaged to the Pearson attachment with proper support to the foot. In this position circulation of the foot can be readily observed.

This external splinting is a necessity and can also be accomplished by the use of moulded plaster and wooden splints. The splints should remain in position until bony union is complete. In this way the contraction of strong muscle groups which often cause post-operative angulation is prevented. We have seen angulation of 45 degrees occurring at the site of fracture without breaking of the plate and with slight displacement of the screws, where proper external splinting has not been applied.

The sutures are removed on the fifth day. After the third day, the patient is encouraged to exercise the muscles of the part by occasionally moving the toes, flexing and extending the ankle joint, and to contract the extensor and flexor groups of muscles of the thigh, so that there is but a minimum of motion of the patella and not sufficient to disturb the fragments at the site of fracture. In this way normal physiological tone of the muscles is preserved and the atrophy is minimum. After the removal of the sutures, with the aid of pulleys and rope through the Pearson attachment, active and passive motion of the knee joint to within certain limits or up to the point of pain is instituted. During this procedure the surgeon should give definite instructions to the patient as to the limits of the same. Active and passive physiological exercise of the part is also maintained by the use of the Smart machine after the first ten days to two weeks. Check *x*-rays made by the portable apparatus in two views, anteroposterior and lateral are taken the day following operation. Union is checked to a certain degree by *x*-ray films and by physical examination. At the end of six weeks a second set of *x*-rays are taken and osteogenesis observed. At the end of eight to ten weeks, according to the union, the patient is measured and fitted with a walking caliper brace. Further check *x*-rays are taken and union permitting, patient is permitted to be up and about with the aid of crutches. In twelve to sixteen weeks the walking caliper brace is discarded and the patient encouraged to walk with the aid of crutches. Within the next four to six weeks the patient has again regained the physiological tone and strength in the muscles, and with osseous union sufficient to permit weight-bearing and re-occupation.

FRACTURES OF THE LOWER END OF THE FEMUR

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THESE fractures may be considered under the following headings:

1. Fractures above the condyles.
2. T-fractures.
3. Fractures of one condyle.
4. Fractures of part of a condyle.
5. Separation of the lower femoral epiphysis.

These all tax the best skill of the surgeon, tending as they do to result in serious incapacity unless adequately treated.

Non-union is rarely a problem in these cases. The difficulty is in the securing of accurate reduction which is so essential if the leg is to be restored to its greatest use. Not the least important part in the treatment is the first-aid care to prevent further damage by careless handling. Before being moved from the site of the accident they should be most carefully protected, preferably in a Thomas splint, with some form of traction. Naturally a like amount of care should be given in the course of the subsequent examination to avoid causing further harm.

1. FRACTURES ABOVE THE CONDYLES

These are not rare and result frequently from falls on the knee. They are sometimes caused by landing on the feet from a height.

These fractures occur at varying distances above the condyles and may be transverse, but in the usual type the break runs obliquely downward and forward, the sharp end of the upper fragment tending to penetrate into the suprapatellar bursa. (Fig. 1.) There is frequently considerable shortening due to the pull of the powerful thigh muscles and the gastrocnemei aid in this by pulling back on the lower fragment. The mobility is very obvious. There is marked swelling in the region of the knee-joint even when this is not directly involved. This comes from vessel damage large or small. The marvel is that the popliteal vessels and nerves are not more often injured, their escape being due to the extent to which they can be displaced without harm. One is struck in approaching the back of the knee-joint to note how these structures can be pulled aside with the fleshy origins of the gastrocnemii.

Every effort should be made to reduce the fracture with the least possible delay. Failure in this leads to serious deformity. (Fig. 2.)

In the transverse fractures reduction may sometimes be accomplished by manipulation under an anesthetic. The obstacle in attempting reduction by manipulation is that the position is apt to be lost in the subsequent splinting of the limb.

The application of a cast is not without risk owing to the added swelling which is likely to follow and another disadvantage is that with the reduction of the swelling the cast may become too loose to maintain the fragments in position.

Hence the method of choice is that of traction and suspension. The use of the Thomas splint with the Pearson hinge has proved of great value. The main splint holding the thigh is elevated to allow the knee to bend at an angle of ninety degrees. Adequate traction on the end of the main splint will exert its pull mainly through the slings at the back of the leg.

Immediate skeletal traction on the condyles by wire, nails, or ice-tongs, while ideal mechanically, is too risky in the presence of much swelling. An infected hematoma may easily result with dire consequences. Such methods may be recon-

sidered at the end of a week when the swelling has subsided if the position is unsatisfactory.

Preferable, however, when skeletal traction is necessary, is the use of a wire or nail passed through the crest of the tibia below the tibial tubercle. During the war we occasionally placed two screws in the tibia at right angles to one another. Through small incisions the lateral one was put immediately above, the medial immediately below the tubercle. Small metal rings slipped over the screw-heads, with the skin protected, gave a means of skeletal traction both comfortable and efficient.

Operative treatment should be undertaken only as a last resort. This is not justifiable unless the skill, judgment and experience of the surgeon make the added risk seem warranted. Laceration of the popliteal vessels, if the diagnosis is clearly established, naturally demands intervention. Aspiration of the knee-joint is indicated in the presence of hemarthrosis.

As soon as circumstances permit, active exercises for the knee should be guardedly commenced and as union progresses every encouragement should be given to restore the knee to its full extension. Needless to say frequent skiagrams should be taken to see that no displacement is taking place.

2. T-FRACTURES

These are fortunately less frequent. They result as a rule from falls on the knee. The vertical line runs into the intercondyloid notch and the condylar fragments are frequently more or less symmetrical.

The diagnosis is made on the great mobility and the marked effusion into the knee-joint. Independent mobility of the condyles may be apparent. Treatment is best effected in a Thomas splint. Skin traction applied to the leg operating through the lateral ligaments may be sufficient if the shortening is not marked. If greater traction is required, a transfixion pin may be placed below the tubercle of the tibia, or the two screw method described above. Twenty degrees of flexion at the knee is adequate. With greater flexion the danger of a varus or valgus deformity is increased. Aspirations of the joint should be done, as the presence of blood in the joint keeps the condyles apart and later increases the difficulty of restoring motion to the joint. The use of a clamp as suggested by Scudder may be of assistance to force the condyles together. This should be applied well padded and removed in the shortest possible time.

These cases seldom require operative interference and it is doubtful if the result is likely to be improved thereby.

An attempt should be made to secure some degree of active movement of the joint by means of the Pearson hinge at the earliest possible time.

When the time comes for weight-bearing the knee should be supported by a walking caliper and this should be worn for several months to prevent a valgus or varus deformity.

3. FRACTURES OF ONE CONDYLE

These fractures arise from forced adduction or abduction of the extended knee, sometimes aided by rotation. The fracture lines vary considerably. Displacement is not usually a feature but the lateral mobility is increased. If an entire condyle is broken off it may be felt to follow the tibia when the leg is abducted or adducted, and crepitus may be noted. This distinguishes the fracture from a severe tear of a lateral ligament.

It is reduced by securing a proper alignment of the leg and is maintained in a plaster cast including the thigh, leg and foot.

As emphasized years ago by Hamilton the knee should be in full extension. This enables one to judge if the leg is in the axis of the thigh.

If reduction is not secured or is difficult to maintain open reduction is indicated to perfectly restore the joint relations. The

fragment may be anchored with a screw of appropriate length or other fixation methods. Some considerable loss of flexion and extension is to be expected if the reduction is incomplete.

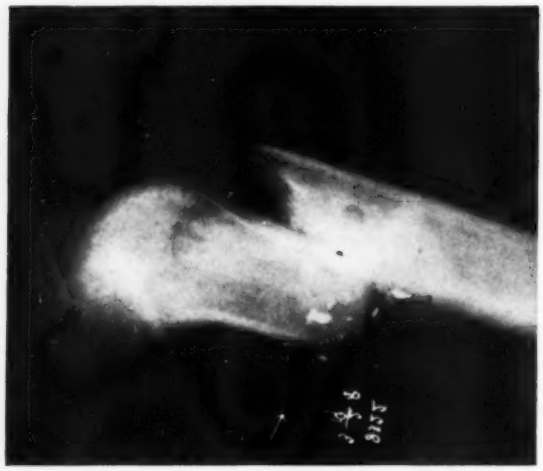

Fig. 1. Compound fracture of lower third of femur. The sharp lower end of the upper fragment penetrates the suprapatellar bursa.

Aspiration of the joint may be required if the effusion persists.

In these cases as in the T-fracture, the knee should be protected upon weight-bearing by a walking caliper. The broken condyle has a tendency to collapse even after a considerable period causing marked lateral deviation of the joint. Adequate support is essential if this is to be prevented.

4. Fractures of a Part of a Condyle

Occasionally one finds portions of the condyle, more frequently the medial, pulled off with its ligamentous attachment. These correspond to similar injuries on the tibia as when the spine of the tibia is broken off through the pull of the anterior crucial ligament.

The clinical picture is that of a tearing of the ligament affected, but the detached fragment may be felt or crepitus noted. A skiagram may fail to reveal the fracture if taken in only one direction.

If the condylar fragment is not displaced fixation in a cast will suffice. The leg should be straight. Pads applied locally may be of use. If markedly displaced it is better to anchor it after reduction. In these cases, too, weight-bearing should be protected for some weeks with a cast or walking caliper to prevent relaxation of the ligaments.

Fig. 2. Characteristic deformity following fracture in the lower third of the femur.

Small fragments may be identified in the *x*-rays as having been detached from the articular surface. Consideration should be given to their removal from the joint if their appearance suggests interference with joint function.

Every knee with ligamentous injury severe enough to require surgical aid deserves *x*-ray examination. I recently saw a patient operated upon a year ago for a torn internal semilunar cartilage whose recovery has been delayed, permanently in all probability, by the associated tearing away of a fragment of the medial condyle. This was not recognized, and as a result he has a very unstable knee.

5. Separation of the Lower Femoral Epiphysis

Separation of the lower epiphysis of the femur once fairly common has become rarer with the displacing by the automobile of the horse-drawn vehicle. The "cart-wheel" injury came to boys hanging on and getting tangled in the spokes.

The mechanism is that of hyperextension and the common displacement of the

epiphysis is forward. The backward variety occurs rarely. The strong posterior ligaments hold and the epiphysis is sheared off. Some lateral displacement may occur. This epiphysis is the largest in the body. The proximity of the popliteal vessels renders them prone to injury by the rough lower edge of the upper fragment.

The prognosis is reasonably good if reduction is done early but delays are especially dangerous. Many amputations have resulted and not a few deaths.

For the forward displacement, reduction under complete anesthesia should be attempted. With full flexion of the knee firm traction is made on the joint, pulling downward and pushing backward on the epiphysis, the foot braced against the operator's body. One assistant holds the pelvis on the table, and a second pulls forward on the lower end of the shaft. Slings of stout material may be of help. Additional traction applied to the foot may assist the surgeon.

In the backward displacement, the knee is likewise flexed and an effort made to replace the epiphysis by traction downward and forward, an assistant pushing backward on the lower end of the shaft.

As a rule the displacement if reduced does not tend to recur. A plaster cast should be placed on the partly flexed knee, to be retained for one month. If the deformity tends to recur, the cast may have to be applied with the knee more fully flexed. Needless to say the circulation must be carefully watched.

Following the removal of the cast active exercises are carried out without weight-bearing until full extension is secured for the knee.

Cases which cannot be reduced will require open reduction. The use of hooks is recommended. I have no experience in this and would make every effort to avoid it.

Skeletal traction on the epiphysis has been used and the pull is of course efficient, but it requires unusual skill to apply correctly and is risky in the presence of extravasated blood. I have seen one case so treated come to amputation because of overtraction with vessel damage.

AN EVALUATION OF RUSSELL TRACTION TREATMENT IN FEMORAL FRACTURE*

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IN recent years increasing interest is being manifested in the Russell traction treatment for fractures of the femur. Introduced in 1924,[14] this method was for some time slow in being generally adopted, but with the gradual accumulation of experience its advantages seem now to have become more widely appreciated. Particularly is this true in greater New York and its vicinity where Russell traction now holds the position of being perhaps the most practical single measure for general use in femoral shaft fracture, having largely replaced the older Thomas splint adhesive traction and for most cases supplanted skeletal traction as well. The use of plaster cast immobilization for early treatment, certainly in adults, is here regarded at present as nearly obsolete. Russell traction is also receiving considerable attention in Philadelphia,[8,3] from which city the first published account of this method in the American literature appeared ten years ago.[15] There are now a fair number of reports on the subject emanating from scattered sections of this country—one[4] from the military service.[13,10,22,6,11,1,12,19,5,17]

To those who have observed the benefits of Russell treatment, it is, however, surprising that this method has not as yet attained a more universal use. Thirteen years have elapsed since its introduction and still it is ignored in some of the leading fracture clinics, only occasionally employed by others, and apparently little known in many localities. Reports in the literature are almost uniformly favorable, in many instances enthusiastic. Yet one finds recent articles reviewing the treatment of large series of femoral shaft fractures by varied methods in which Russell traction has been totally disregarded.[2,20,23,21] Also in late editions of several authoritative text books on fractures there is little mention of this method and even that usually not based upon personal experiences of the author. This latter is particularly to be regretted, since it serves to deprive many who rely chiefly on text-books for their information, of a means of treatment which might be particularly useful to them.

It seems hardly necessary in this age to offer an argument for suspension-traction as opposed to plaster fixation in handling fractures of the shaft of the femur. We do feel, however, that a plea should be entered for the more general adoption of the Russell apparatus, embodying as it does the best features of traction treatment and adding simplicity and economy as well. The method is physiologically sound, being founded primarily upon the principle that when relaxation of the muscles of the thigh has been attained, the bone fragments can be eased back into their normal relationships by a minimum of pull. With the surrounding muscles at rest, correct alignment of the fracture is maintained without the need of external splinting because there then exists no active force to displace the bone. The method is diametrically opposed to that of reduction by manual or mechanical force as ordinarily used. It serves as a graphic example of what gentleness can sometimes accomplish where sheer power often will fail. In our experiences these principles have proven in practice as well as in theory to hold true.

* From the Surgical Services of the Beekman Street Hospital.

THE RUSSELL TRACTION METHOD

The materials required for the institution of Russell traction are inexpensive, readily obtainable and easily set up. This is one of the chief features of the method. Details of the apparatus and its mode of employment have been so frequently and completely given in earlier publications on this subject that it would be repetitious to offer them again. The best of these is still that by Russell[14] which contains illustrations, diagrams and full descriptions of the technique. For the details reference is made also to several American publications, most of which have incorporated the illustrations and portions of the text of Russell's paper.[8,15,13,10,22,18] Some modifications have been made in the original apparatus but these are for the most part relatively unimportant. They do not alter the method intrinsically but are concerned only with the form of the overhead frame and the lower pulley attachment,[1,19,9] We have found the ordinary Balkan frame to be entirely satisfactory, and the double pulley devised by Lowry[9] particularly convenient for the economy of space in a crowded ward.*

With the purpose of systematizing the Russell traction treatment we evolved an outlined scheme, to guide its general use, which was published earlier this year.[16] This suggested routine was not intended as a modification or alteration of the original method, but aimed rather to accentuate specific details in its employment which seemed to merit special emphasis. It has served to instruct the house staff in the application of the basic principles of the apparatus and has proven of value for this purpose. We have found that in order to obtain maximum traction efficiency, particular attention must be paid to the angles at which the hip and knee are held in suspension. Specifically we advocate 20 degrees of flexion and not over 15 degrees of abduction at the hip and 20 degrees of flexion at the knee. These angles we regard of sufficient importance to require their actual measurement in each case treated by this method. Study of the mechanics of the apparatus support the contention of the necessity of correct angle pull[14,15,9] and clinical observations have repeatedly confirmed this opinion. We have had several cases in which persistent displacement was found to be due to lack of sufficient regard for this factor and was corrected by proper suspension of the extremity. The addition of more traction weight alone will not compensate for faulty adjustment of the apparatus. Simplicity of design does not imply the tolerance of carelessness of execution, certainly in this instance. Some of the failures attributed to this method, we believe, are due to the fact that those surgeons were under a misapprehension when they assumed that they were treating their patients by Russell traction.

Lest the foregoing should create the impression that this method is in reality complex and requires too much attention to warrant its general use, we wish to add that such is not the case. With a little experience, standardization of the technique and sustained interest, it soon comes to be handled easily as well as correctly. But thoughtful regard for details cannot be dispensed with. It does demand constant supervision, most of which can be adequately done by the nursing and house staffs as soon as they have been properly instructed in the use of the apparatus. The benefits to be gained justify these efforts.

We have continued to use the routine previously described[16] with only a few minor changes. As a check-up on the length of the fractured extremity, measurement by tape has not proven sufficiently accurate and has been discontinued. During the early period of treatment there is no substitute for frequent examination by *x*-ray film or fluoroscope. At times, daily roentgenological studies are necessary. For this purpose a portable *x*-ray unit is essential and this treatment should not be undertaken unless such equipment is available.

*A brief description of the Russell traction method is given in the article on *Non-Operative Treatment of Fractures of the Shaft of the Femur*, on page 636 of this issue.

The occasional use of lateral traction bands has been added and has proven a helpful adjunct for correcting malposition. Side pull was also found of value in the only instance in which it was tried to overcome persistent external rotation. The use of side traction, which we subsequently found to have been previously mentioned[11] is rarely required but apparently can be applied as an additional measure in some cases without disturbing the mechanics of the traction apparatus. It is recommended that the lateral band be guided in an obliquely downward direction so as to counteract as little as possible the desired resultant axial pull.

EXPERIENCES WITH RUSSELL TRACTION

In our published series of twenty-nine cases of femoral fracture[16] the Russell method proved adequate in twenty-four. It is significant that, in four of the five patients who could not be satisfactorily handled by this means, the fracture involved the lower third of the bone. The fifth had a transverse fracture of the midshaft with soft tissue interposed between the fragments. In each of the five, manipulation under anesthesia was attempted at least once without effecting reduction. Three of these patients had in addition a trial of skeletal traction without improvement. Open operation with metal plating was finally resorted to in four of these cases. The patients were then returned to Russell traction, and satisfactory end-result obtained. The other twenty-four cases proved amenable to Russell treatment, although supplementary manual reduction was sometimes necessary. These patients were not removed from their beds for the manipulation and in all the traction was resumed and carried on to completion of the treatment.

We have subsequently employed Russell traction in twenty-three additional cases of femur fracture with results similar to those obtained in the earlier series. Of these, eight were midshaft fractures, all of which were found suitable to the treatment. This group was a varied one containing oblique, spiral, comminuted and transverse fractures. There were six intertrochanteric cases and one of subcapsular neck fracture, all of which were handled with relative ease. In four, the upper shaft was fractured. Three of these were maintained in the Russell apparatus throughout their course but one was changed to skeletal traction, after a brief trial in Russell traction, because of failure to correct malposition. As with our earlier cases, the greatest difficulty came with the lower shaft fractures. Due to previous unfavorable experiences, Russell traction was attempted in only four of these. In two it was successful but the other 2 required skeletal traction and one of these finally came to open operation. Of the present group, seventeen of the twenty-three were adults over the age of 16; none was under 5 years of age. Adequate anatomical restitution was aimed for and secured in each case. All went on to firm union and none showed deformity or significant shortening when seen for late examination.

Except for supracondylar cases, Russell traction remains in general use by us for all fractures of the shaft of the femur in patients 5 years of age or older. In low shaft fractures it is given a period of trial in each case but is replaced by skeletal traction if early improvement does not occur. Our experiences have taught that most fractures in the lower shaft are not adaptable to this method. Results have been favorable in midshaft cases although transverse fractures at this site have not been easily handled. Russell traction has also proven satisfactory in the treatment of fractures in the upper shaft and has been invariably successful when used for intertrochanteric cases.

In many cases, marked deformity has been spontaneously reduced in the traction apparatus. Supplementary manipulation under anesthesia is not infrequently required to aid in effecting reduction and can be carried out without interrupting the treatment. In all cases continual surveil-

lance, check-up on the angles of pull and readjustment of the apparatus, are necessary. Periodic examination by *x*-ray is essential to guard against displacement and forestall the likelihood of overpull. The danger of this latter complication should be particularly stressed. The relatively small traction weight can be disarmingly powerful, especially to one who is accustomed to the greater weights commonly used with skeletal traction. Separation of fragments due to overpull has been found to be a frequent cause of delayed union.

COMPARISON WITH OTHER METHODS

Through a study made by Kennedy[7] and recently presented before the New York Surgical Society (March 10, 1937) the opportunity was afforded for direct comparison between Russell traction and other methods of femoral fracture treatment in a similar series of cases under identical conditions. Kennedy reviewed the experiences at the Beekman Street Hospital with fractures of the femur during the eight year period (1924–32) immediately prior to the adoption of Russell traction at this hospital. During these years, adhesive traction in Thomas splint and skeletal traction were employed at this institution with about equal frequency. A small number were treated by reduction and plaster cast immobilization. For children under 5 years of age, Bryant overhead suspension was the preferred treatment.

While the end-results were equally good and the period of hospitalization on the average somewhat shorter in his series than in the Russell traction group, the findings of Kennedy's study serve further to accentuate the advantages of the Russell method. The frequent failure of Thomas splint adhesive traction to secure or maintain satisfactory reduction (in 43 per cent of cases) and the high proportion of tong and pin wounds (50 per cent) is a striking arraignment of those methods. Primary plaster encasement, he agrees, has little place in modern femoral shaft fracture treatment. The older type of adhesive traction is proven on review to be strikingly inadequate. Skeletal traction is undoubtedly efficient but the problem of local infection with it is a serious one and supplies a strong argument against the use of direct bone pull, particularly when a nearly equally efficient and certainly safer means of treatment is available. To be sure, most of these infections were of minor degree, but in 17 per cent of Kennedy's cases the bone was involved and one patient still had draining sinuses when last observed thirty-one months after the tongs had been withdrawn. Open operation with internal fixation seems to be the ideal form of treatment, but in most instances and under usual circumstances is quite impractical as a method for general use.

Basis for further comparative evaluation of the Russell traction method is supplied by two recently published reviews of experiences with femoral shaft fractures, in neither of which this method was employed. Weil, Kuehner and Henry[23] resorted to open operative procedures in over 37 per cent of their cases and had five infections, with two deaths from septicemia. In a series of 105 cases from the Massachusetts General Hospital, Van Gorder[21] found it necessary for open operation to be done in 21 per cent of children and 25 per cent of adults with fractures of the shaft of the femur. In those operative cases the incidence of infection was 15.4 per cent. He further reports that 25 per cent of the cases in this series treated by traction (not Russell) showed shortening of the extremity after union had been obtained.

More recently, Eliason and North[3] reported on seventy-four similar cases, of which fifty were under 16 years of age. They attempted Russell traction in thirty cases but sixteen of these were given only a brief trial in this apparatus and the type of treatment changed when insufficient improvement was noted. In the light of our experiences their poor results are difficult to understand, but it is suggested that given more time in Russell traction

some of their cases might have done better. We have noticed improvement in some of our cases during the second week of treatment with persistence of the method and adjustment of the apparatus. In their series, open operation was done in 33 per cent of the adult patients and in 14 per cent of children—seven for failure in Russell traction. Open operation was done in only six (11.5 per cent) of our total Russell cases. Following operation they report one result with osteomyelitis and shortening and four with considerable disability from impaired knee motion. It was apparently their practice to use plaster cast immobilization after operation. This may account for their difficulties with joint function. We have found the Russell apparatus particularly useful after open operation and that with it joint motion is rarely impaired.

For the treatment of fractures of the femur, varied methods are available to the surgeon. Fundamentally these come under one of three main types: Manipulation and immobilization by plaster of Paris spica, suspension and traction by adhesive or skeletal pull, and open operative reduction with internal fixation. Each of these modes of treatment has several possible variations or modifications. Reduction may be manual or mechanical and the immobilization in plaster may be augmented by pins or wires incorporated in the cast or by attachment to the opposite extremity. Adhesive traction may be with the Thomas or Hodgen splint or may be employed as by Russell without external splinting. For skeletal traction there are tongs, pins and wires which may be inserted into the femur or upper tibia. Any of the forms of traction may be augmented by manual manipulation. With open operation there are various ways of securing internal fixation, to be followed by either plaster encasement or some form of traction to assist in maintaining correct position.

With many means at his disposal the surgeon need not limit himself to any set form of treatment for femoral fracture. No one of these methods is by itself ideal; each to a greater or lesser degree has its advantages and deficiencies. The treatment adopted in any specific case should be that best suited for the pathological state which exists while taking into consideration the constitution of the patient, the experience of the medical attendant and the facilities and equipment available. Furthermore, the surgeon who attempts to care for a major fracture of this type must be prepared to alter his course and change from one type of treatment to another if after due trial the method adopted does not seem likely to achieve the best possible result. It must, however, be conceded that the simplest method is the one to be favored if it will attain this goal.

Standardization of femoral fracture treatment is not in itself a desideratum. The advocation of routine practice is not our intention. There is much to be said, however, for the formulation and specific tabulation of basic rules to serve as a guide in the adoption of a method of treatment of which one desires to form a critical opinion. These can be changed as experience dictates.

With this thought in mind the outline of Russell treatment previously given[16] was followed at the Beekman Street Hospital during the last five years. In the latter two years of this period the method was not used in all shaft fractures, as accumulating experience exposed its limitations as well as its advantages. Results on the whole have justified the effort expended. The method has proven of real value, in most cases, and we believe it constitutes a real advance in the treatment of fractures of the femur. Our results, we feel sure, can be duplicated by all who will concentrate on its use and give it a thorough trial.

ADVANTAGES AND LIMITATIONS OF RUSSELL TRACTION

Further experiences with Russell traction have served to emphasize its many advantages. The apparatus is efficient, economical, easily available and readily

installed. Patients can be transferred into it with minimal risk of losing the good position so frequently present when proper emergency traction has been used for transportation. The patient is immediately made comfortable and remains so throughout the treatment period. The method is especially useful in the care of the aged with femoral shaft fracture and also for children whose cooperation is not necessary for its successful employment. From the nursing standpoint it is particularly satisfactory; linens can be changed, bedpans passed, associated injuries treated and backs cared for with little danger of disturbing the apparatus. Dressings of compound wounds are facilitated. Changes of the moleskin adhesive strips are rarely necessary even in prolonged cases. Physiotherapy can be instituted early, given frequently and continued as long as needed. Muscle atrophy is minimized and joint motion invariably preserved. The method is strikingly effective for the treatment of most cases of femoral shaft fracture. With it, good alignment is usually maintained and malposition often spontaneously corrected. When required, manual manipulation can be added without interrupting traction. The necessity for skeletal traction and open operative procedures with their additional risks is in most cases obviated.

The advocation of Russell traction treatment calls for a word of warning in its use. The method is a practical one but by no means self-running or fool-proof. It cannot be put on and left to look after itself. To render efficient service the apparatus must be applied with thoughtful regard to its mechanical principles, and to insure against unsatisfactory results requires constant supervision and frequent adjustment. Hospitalization of the patient is usually necessary and the period of bed confinement is relatively long. Portable *x*-ray equipment must be available. Russell traction is not the method of choice in every fracture of the femur. It should never be used for intracapsular neck fracture except where bony union is not anticipated. Its use is not recommended for most low shaft fractures, and for supracondylar cases it is better not attempted. Even for suitable cases this method often requires, during phases of its employment, supplementation by other procedures—at times temporary substitution by other modes of treatment, at other times its abandonment in cases where for awhile it seemed to work with complete satisfaction. Properly and judiciously employed, the method offers infinite possibilities of usefulness. Indifferently practiced, it will give inferior results and obtain unmerited disrepute.

CONCLUSIONS

1. The Russell traction method is a useful addition to the armamentarium of femoral fracture treatment and is worthy of wider recognition.

2. To insure best results the limitations of the method must be realized.

3. Its use should be reserved for suitable cases.

4. The apparatus must be meticulously applied and constantly supervised. The availability of portable *x*-ray equipment is an absolute essential.

5. Properly employed, Russell traction represents a real advance in the treatment of fractures of the femur.

6. Experiences with it are favorable in comparison with those obtained by other methods when the many advantages of Russell traction are considered.

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"As a rule, they [pressure sores] are not the result of insufficient padding, but are the result of improper holding of the extremity while the cast is applied or of improper application of the bandage. Sometimes a pressure sore results from a deep indentation in the plaster made by the assistant's hand while it supports the extremity."

SKELETAL TRACTION IN FRACTURES OF THE LOWER EXTREMITIES

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IN the days before skeletal traction, immobilization in plaster of paris, traction and suspension by adhesive plaster, and open reduction, were the three main methods in vogue in the treatment of fractures of the lower extremities. Nor are these methods obsolete today. Each will still produce satisfactory results if applied at the proper time in suitable cases. However, we know that fragments in good position immediately after application of plaster of paris may show slipping and unsatisfactory position ten days later. We know that in the muscular and obese, skin traction may prove ineffective. We know that every general surgeon is not qualified to perform open reductions of fractures. Only those possessing the necessary mechanical instinct, combined with special training, experience, and adequate equipment in an operating room where absolute asepsis can be maintained, should permit themselves to take the risks entailed in this work. In skeletal traction, accordingly, we have an additional string to the bow of fracture therapy.

HISTORICAL

Even in pre-antiseptic times the idea of skeletal attachment had occurred to surgeons. Malgaigne devised an apparatus armed with double hooks to approximate distracted fragments of a broken patella. Naturally the infection which followed discouraged its widespread adoption.

In 1900 Heinecke devised tongs to grasp the calcaneus. The disadvantage of these lay in the fact that they had to be tightened from time to time and if this were not done, the constant pull led to gradual slipping of the points along the bone and tearing of the soft parts.

In 1903 Codivilla, the Italian orthopedic surgeon, first used the nail to overcome shortening in fractures of the thigh. A nail was driven transversely through the calcaneus. Two long flat narrow iron strips reaching from the sole of the foot almost to the knee, with perforations for the nail near their lower ends, were incorporated in a typical plaster of paris spica reaching from ankle to pelvis. After the plaster had hardened, a circular division of the cast was made opposite the site of the fracture. Under anesthesia and on an orthopedic table, distraction of the two halves of the cast was made, the pelvis being fixed and screw traction beyond the foot applied to the projecting nail-ends. Shortenings up to 6 cm. were overcome by this method. The object in using the nail was to avoid decubitus over the dorsum of the foot and heel. In one case Codivilla actually tried distraction in a fracture of both bones of the leg, driving one nail through the upper end of the tibia and another through the calcaneus, incorporating all projecting ends in a plaster cast.

Steinmann[1] of Berne (in 1907) was the first to use constant skeletal traction, by means of a method which he called *nail extension*. His first apparatus consisted of two nails driven obliquely into the condyles of the femur and held in place by a suitable metal clamp; practically, this constituted a tongs effect, to which constant traction was applied. After a short time he discarded this method in favor of another, employing a nail transfixing the lower thigh and femur one finger's breadth above the upper margin of the condyles. To the

projecting ends of this nail was fitted a horseshoe-like steel holder in two halves. A thumb-screw locked the two halves together where they crossed after each half had been fitted to the corresponding nail end. (Fig. 1.) To this apparatus were attached a rope and weights for constant traction combined with suitable suspension.

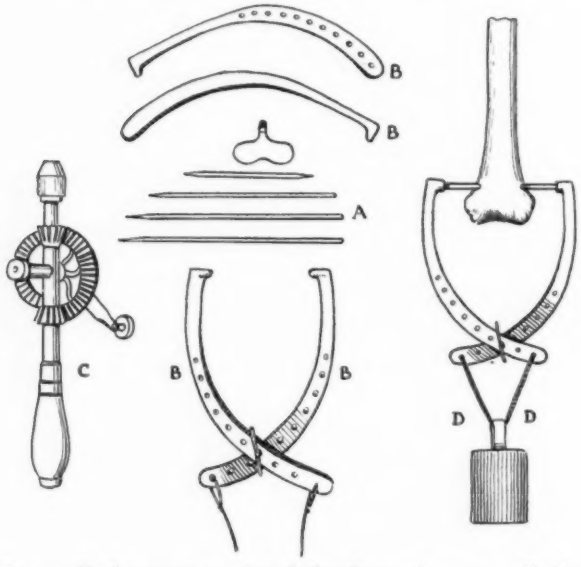


Fig. 1. Steinmann set for skeletal traction: A, nails in varying lengths; B, two-piece tongs with locking thumb-screw; C, hand drill into chuck of which round head of nail is fastened; D, skeletal traction apparatus in place. Note that in B and D traction is applied to ends of crossed limbs of two-piece horseshoe to assure contact with nail ends in case thumb-screw should loosen.

In 1912 and 1913 during the second Balkan War, Klapp, on duty at the Military Hospital in Belgrade and lacking Steinmann nails, improvised *skeletal traction by means of wire* through the calcaneus. (Fig. 2A.) A hole was drilled transversely through the calcaneus and through this a wire was drawn. The projecting ends of wire were threaded on needles which were passed back through the holes of exit until the needle points met the surface of the calcaneus, and then were turned downward to perforate the sole of the heel. The emerging ends of wire were then fastened to a suitable yoke or spreader to which traction was applied.[2] (Fig. 2B.) In this procedure Klapp used doubled aluminum-bronze wire, and from his very first publication he insisted that the wire must so be applied that no lateral pressure on the soft parts be produced.

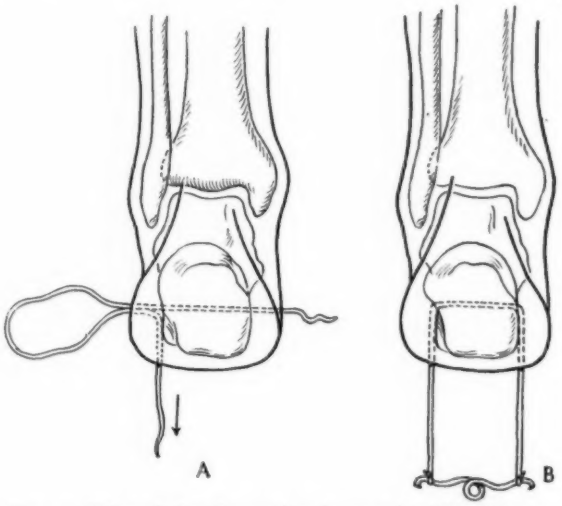


Fig. 2. Wire skeletal traction improvised by Klapp. A, wire passed through previously drilled hole in calcaneus. One end of wire re-introduced through hole of exit in soft parts and brought out through sole of heel to afford direct pull upon bone without pressure on soft parts. The same procedure on inner side. B, both ends of wire now attached to spreader, ready for application of constant traction.

The World War brought a further development when Herzberg devised an apparatus to keep wire taut. He used either a heavy metal ring completely encircling the limb, provided with holes through which wire ends could be drawn and *then tightened*, or simply a horseshoe (or half ring) for the same purpose. The thin taut wire, which served just as effectively as the thicker nail, was a great advance over the old method. Gradually, taut wire replaced nails in vogue, because, with its smaller diameter, the wire proved less irritating to both soft tissues and bone and was less prone to be followed by bone fistula or infection along its tract. It was found, therefore, that wires could be left in place much longer than the four or five weeks' limit placed upon the nail extension method of Steinmann.[3]

In the various forms of skeletal traction by wire in vogue about this time, a hole would first be drilled through the bone, and a wire, threaded through a hole in the

projecting drill point, was drawn back with the drill on its withdrawal.

Further progress occurred when, in 1927, the sites of fracture, and their ends securely fastened in an adjustable distraction apparatus. Shortening, angulation and rotary

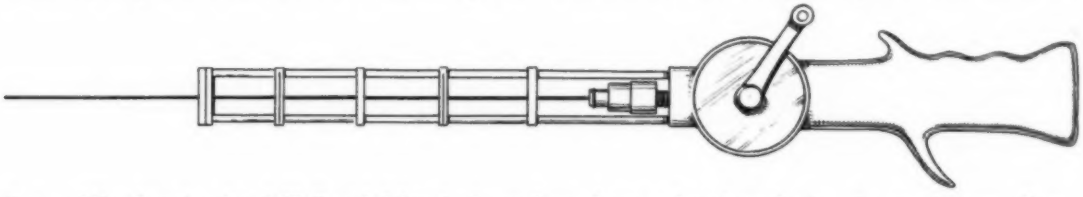


Fig. 3. Kirschner's wire drill (hand driven). A rustless, sharp-pointed steel wire of 1 or 1½ mm. diameter transfixes bone and soft parts. The telescopic guard keeps the rotating wire straight and shortens automatically as the wire advances through the limb.

Kirschner[4] used a sharp, pointed, rustless steel wire of 1 mm. diameter as a drill in itself, just as Steinmann originally used his nail as a drill. Kirschner's wire drill was made possible by a telescoping guide (Fig. 3) which held the rotating wire straight, while rotation was secured either by hand or by electric motor. Once the wire had transfixed bone and soft parts, both the projecting wire ends were fitted into a flat horseshoe-shaped steel spreader. (Fig. 4D.) On the inner side of the limb the wire was firmly clamped (Fig. 4A), and to the end of the spreader on the outer side of the limb a special tautening mechanism (Fig. 4C) was fastened. This put the rustless steel piano wire on tension; the end was clamped firmly in place, the tensor removed, and any surplus wire clipped off. With this apparatus, traction up to 60 pounds (30 kg.) has been used without the 1 mm. wire cutting through the bone.

Distraction. As soon as the feasibility and advantages of skeletal traction were recognized, a whole host of authors, beginning with Steinmann himself, devised all sorts of apparatus using the principle of distraction between two or more points of skeletal attachment. Notable in this work were Klapp and Block abroad (Fig. 5) and Roger Anderson in this country. (Figs. 6 and 7.)

Roger Anderson[5] uses Steinmann pins for his well leg *traction* apparatus (Fig. 6), and he has devised ingenious special *distraction* machines for fractures of both bones of the leg and of the femur. (Fig. 7.) Nails are inserted both above and below displacements are corrected under *x*-ray control. This absolute fixation is then taken over by plaster of paris casts which assure maintenance of reduction and per-

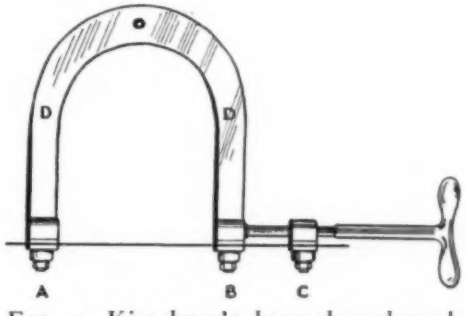


Fig. 4. Kirschner's horseshoe-shaped spreader. At A, wire is firmly clamped. Apparatus at C is putting wire on stretch. When the wire is taut, the clamp at B is tightened, the apparatus at C removed, and the surplus end of wire cut off.

mit of almost immediate ambulation. (Fig. 7.)

APPARATUS

Steinmann Pins. These come in varying lengths comparable to the diameters of the limb at different points of transfixion. The nail, after insertion, should project at least 1 inch beyond the skin surface on either side of the limb. The nail in itself is a drill, which cuts its own way through bone and is then left in place. Some men prefer to use a handle keyed to the head of nail, and others, including the author,[5A] advocate some form of brace to rotate the nail as it bores its way through the bone. (Fig. 1.)

Kirschner Wire. The wire designed by Kirschner is of rustless steel 1 or 1½ mm.

in diameter, held in a specially designed brace with an automatically telescoping guide to keep the rotating wire from kinking as it penetrates the soft parts and bone. (Figs. 3 and 4.)

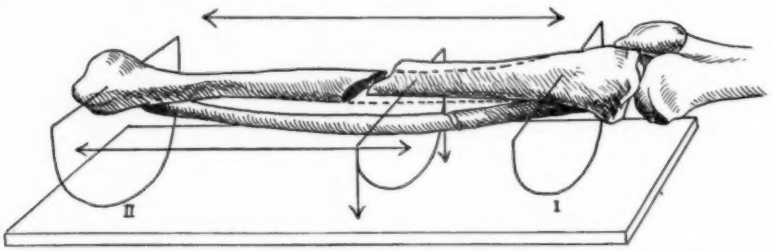


FIG. 5. Diagrammatic scheme, showing distraction between two points (I and II) of skeletal attachment to overcome shortening in a fracture of both bones of leg. Transfixion near lower end of upper fragment permits correction of anterior displacement by drawing backwards at this point. (*After Klapp and Block.*)

Tongs. Many types of tongs have been advocated since 1900 and even earlier. However, these are dangerous even in skilled hands because of their tendency gradually to slip, with resulting necrosis and infection of the soft parts. Indeed, infections attendant on such slippings of tongs, originally placed in the supracondylar region above the knee, have actually led to amputation and even death.

APPLICATION OF METHOD

All parts of the apparatus should be tested before sterilization. The nail or wire is placed in the drill and firmly fastened into place; the drill is then rotated. At times the chuck, which holds the wire or nail, sticks, or the moving parts of the hand control may have become gummed. It is far better to have these in working order before sterilization than to regulate them at the time of insertion when the patient is already under anaesthesia. Extra nails or extra lengths of wire should always be on hand in case one is accidentally dropped on the floor.

At the time of insertion, two assistants are necessary; one to control the foot, the other to maintain countertraction and steady the limb beyond the point of insertion.* The hip, knee, and ankle must be brought close to the edge of the table, in order to leave the operator's hands free and to avoid damaging the knuckles against the margin of the table. The assistant in charge of the foot, while maintaining traction, raises the foot well off the table to allow painting of the limb completely around and well above and below the site of insertion. After sterile drapes have been slid beneath the elevated limb, it may be lowered again. It is well to cover the opposite leg with sterile drapes. The strictest asepsis should be observed to avoid inadvertent contamination. The operator should be gowned, capped, masked and gloved in the customary manner.

The outer margin of the foot must be vertical. It is well to leave as much of the limb exposed to view as possible, thus affording the operator opportunity to see that the pin or wire is passing directly from side to side.† The point of the nail or wire is inserted horizontally and at right angles to the shaft of bone, through the skin and soft parts until bone is touched. The sterile gloved left hand is an excellent guide in

* In a supracondylar insertion of a nail or pin through the femur, it is especially important for the assistant steadying the thigh to pull strongly upwards (cephalad) upon the skin and soft parts of the thigh before insertion of nail is begun. This avoids pressure upon the skin distal to the emerging wire or nail points after traction is applied.

† The author knows of one case in which this was not done and the nail transfixed the external popliteal nerve, producing complete peroneal palsy.

Improper placing of nails or wires often follows the use of too voluminous drapings which leave only the site of transfixion exposed. Should the first wire be improperly inserted, it may be left temporarily in place to act as a guide while a second wire is being correctly applied.

estimating exactly where bone lies. Drilling is now begun, with pressure sufficient to keep the drill in contact with the bone. It is not necessary to press too hard, since the drill cuts its own way if the wire or nail is kept rotating. The corticalis offers considerable resistance, but there may afterward be a sudden jump of ½ inch as cancellous bone is penetrated. Progress is again slower as the corticalis of the opposite side is encountered, but finally this is passed and the nail or wire point may be felt emerging from the bone. (The assistant must be sure to pull the skin and soft parts upwards as these are being penetrated in the supracondylar region.) When the nail or wire projects equally on either side of the limb, sterile gauze pads are run down to the skin along their projecting points. The author prefers dressings of aristol and collodion, directly around the points of emergence. Surplus iodine may be removed by pouring alcohol over the limb.

The two-piece tongs, in case a nail has been used, or Kirschner's horseshoe apparatus for holding the taut wire, are now applied (see above).

A multitude of methods for traction-suspension are now in vogue, since almost everyone has certain predilections, depending on his personal taste and mechanical ingenuity. Thomas splints with a Pierson leg-piece allowing bending of the knee are used by many.

Where splints of this type are used, accurate counterbalancing must be instituted so that when the patient raises himself for a change of bedding or to use the bed pan, the entire apparatus follows upwards and no angulation at the site of fracture occurs.

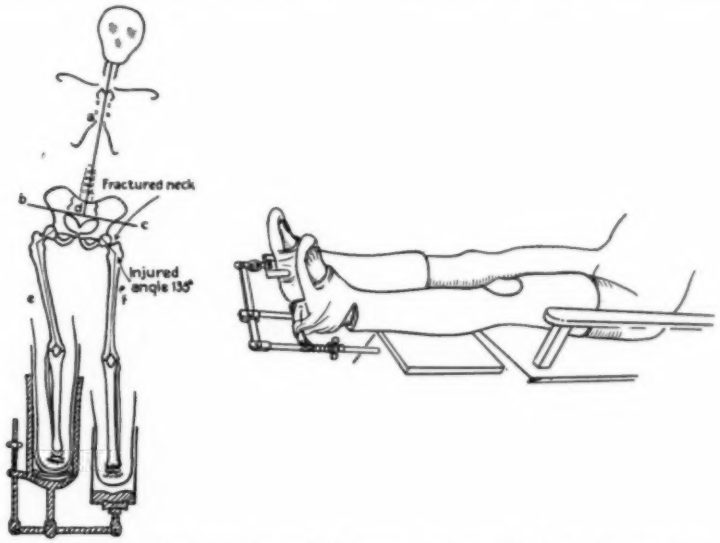


Fig. 6. Roger Anderson's well leg traction method, to be used in fractures of the hip and thigh.

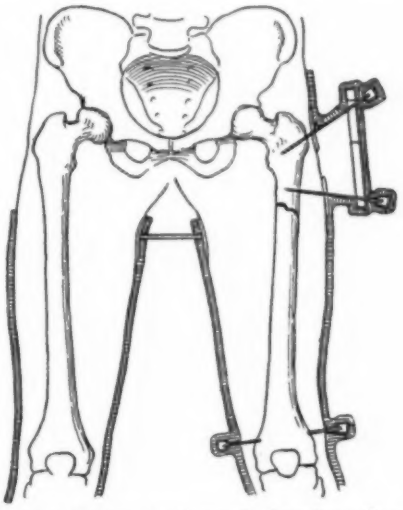


Fig. 7. Roger Anderson's fixation after reduction by distraction in fractures of the thigh.

Böhler, Braun, and others cradle the leg upon special splints, which maintain the knee in partial flexion. (Fig. 8.) A webbing passed beneath the limb from side to side

affords the necessary support to prevent posterior angulation. The Böhler and Braun splints rest upon the bed, which is

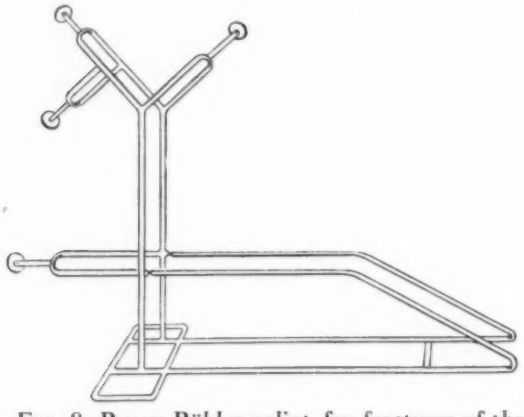


Fig. 8. Braun-Böhler splint for fractures of the femur with multiple pulleys. Unless this splint is firmly fixed to the foot of the bed and the splint itself rests on a flat surface, displacement of the apparatus is sure to occur.

kept level by means of boards placed between mattress and springs. *A specially devised brace fixes these splints to the foot of bed, preventing inadvertent displacement.*

In many instances there is too much complication of apparatus, and a satisfactory position may often be maintained by simpler means, such as Block's suspension of the entire limb in stockinet. (Fig. 9.) The author has found that simple suspension in slings for the thigh or leg often suffices. (Fig. 10. For further details see text below under details of treatment.)

However, left to himself, the patient tends to move towards the foot of the bed, so that eventually traction becomes ineffective. To prevent this, (a) the foot of the bed should be elevated 6, or even 12 inches; (b) a box 6, or even 8, inches in depth must be placed so that the foot of the sound limb can push against it; (c) two hand holds should be conveniently affixed to the overhead frame (Fig. 10). By these means the patient can not only push with his well leg, but also pull with his hands, so that his buttocks may be raised off the bed for change of bedding, etc.

With young children a padded sling, passed through the crotch and fastened to the head of the bed beyond their reach, checks sliding toward foot of bed. They quickly learn to pull themselves upward to prevent pressure on perineum.

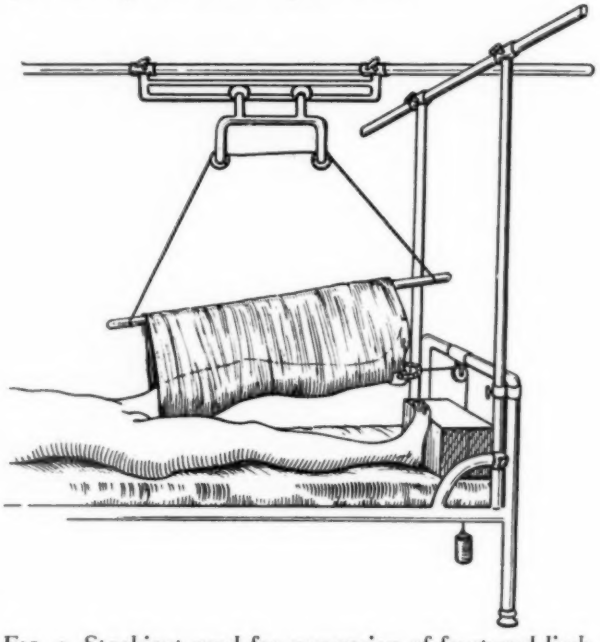


Fig. 9. Stockinet used for suspension of fractured limb, according to Klapp.

Once traction is properly applied and the patient is comfortable, there is no need for him to lie flat on his back. With a suitable back rest, he may sit up for meals and reading, and he should be instructed to exercise both his arms and the well leg several times daily to keep up his general muscular tone.

DETAILS OF TREATMENT

Customary Sites of Attachment. Skeletal traction by transfixion should avoid: (1) hematoma at the site of fracture;* (2) the joint capsules; (3) in children, the epiphyseal lines. (Steinmann.)

The customary sites of attachment are:

1. *Supracondylar.* The nail or wire is inserted transversely one finger's breadth above the upper margin of the femoral condyles. This is done for fractures of the femur in the middle or upper third. (Fig. 11A and C.)

* Occasionally certain authors, using Kirschner wires, have transfixed the hematoma and not experienced infection. This, nevertheless, is risky.

2. *Upper Tibia.* In fractures of the lower third of the femur (supracondylar), nail or wire is inserted through the upper end of the tibia only, two and one-half fingers' breadth below its upper margin on a level with the lower margin of the head of the fibula. (Fig. 11B and C.)

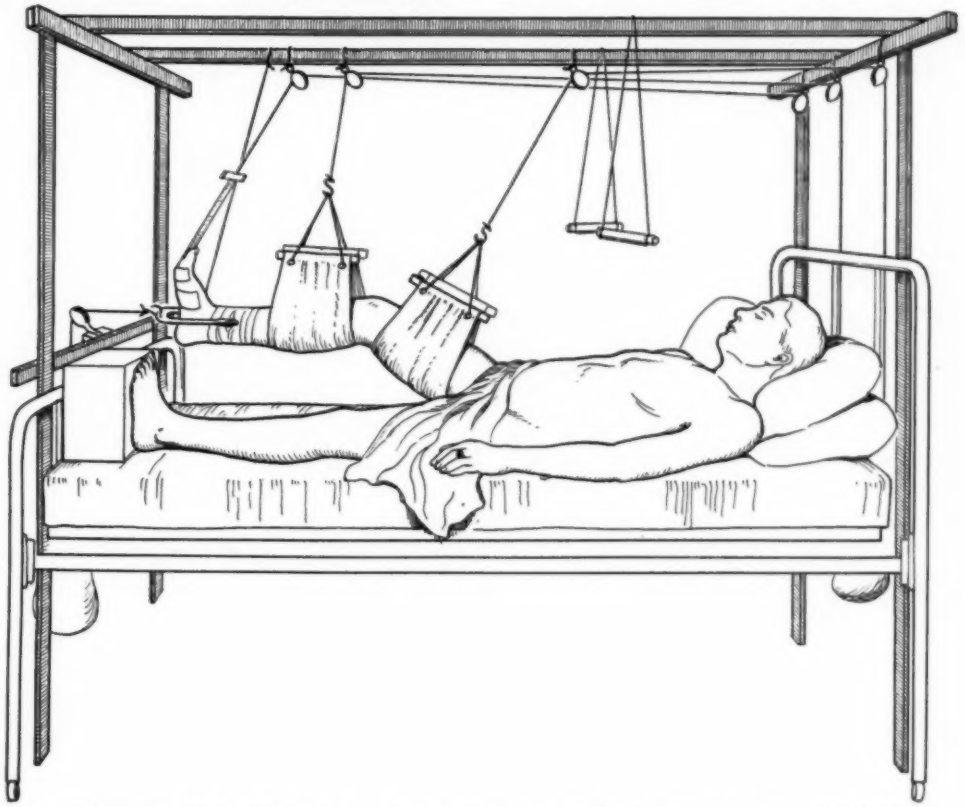


FIG. 10. Supramalleolar skeletal traction and suspension for fracture of upper third of tibia. Note suspension of thigh and leg by cloth slings, counterbalanced and with wooden battens to keep them from narrowing. Drop foot prevented by slipper of adhesive plaster, counterbalanced. Box at foot of bed for well leg to push against. Suspended hand grips. Elevation of foot of bed not shown.

3. *Lower Tibia.* In fractures of both bones of the leg in the upper two thirds, the transfixion point is through the tibia only, two fingers' breadth above the ankle joint or three fingers' breadth above the internal malleolus. This site of attachment seems to merit wider use than heretofore, since the tibia at this point is very strong and consequently traction does not tend to cut through soft parts or bone; the ankle joint can move freely and, if the foot is suspended properly, there is no pressure on the sole. (Fig. 12.)

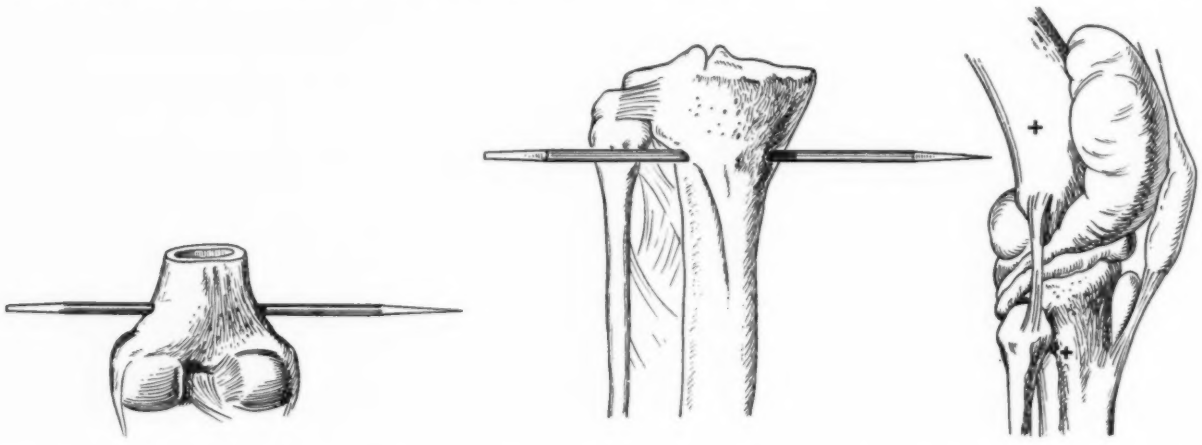
4. *Os Calcis.* For fractures of both bones of the leg just above the ankle, the nail or wire transfixes the calcaneus one and one-half fingers' breadth below and behind the malleoli. (Fig. 12B.)

As the scope of this paper does not permit space for details of skeletal attachment in fractures of the calcaneus and other tarsal bones, the metatarsals, etc., the reader is referred to the fourth English edition of Boehler.[6]

Methods of Insertion. 1. *Hammering (Nails).* This was soon abandoned, although under circumstances where the usual equipment is lacking it still may be used.

2. *Boring by Hand.* A T-shaped handle fitted to the squared head of the Steinmann nail permits transfixion of the bone as though with a gimlet. As previously stated, in the earlier days of the use of wire, various gimlet-like drills, with holes close to the point, were used. Through the hole wire was threaded, so that it was drawn through

the bone upon withdrawal of the drill. Boring by hand, either with a brace or with a geared hand-drill, is the best, safest, and simplest method for the insertion of either the Steinmann nail or the Kirschner wire. (Figs. 1 and 3.)



A B C

FIG. 11. A and C, supracondylar site of attachment. In fractures of the femur in middle or upper thirds, the nail or wire is inserted transversely one finger's breadth above the upper margin of the femoral condyles. B and C, upper tibial site of attachment. In fractures of the lower third of the femur (supracondylar) nail or wire is inserted through the upper end of the *tibia only*, one and one-half fingers' breadth below its upper margin, on a level with the lower margin of the head of the fibula. (*After Steinmann.*)

3. *Drilling by Electric Motor.* This is dangerous in unskilled hands, as the rapidly revolving drill may slip off bone and injure vascular or nervous structures before the power can be shut off.

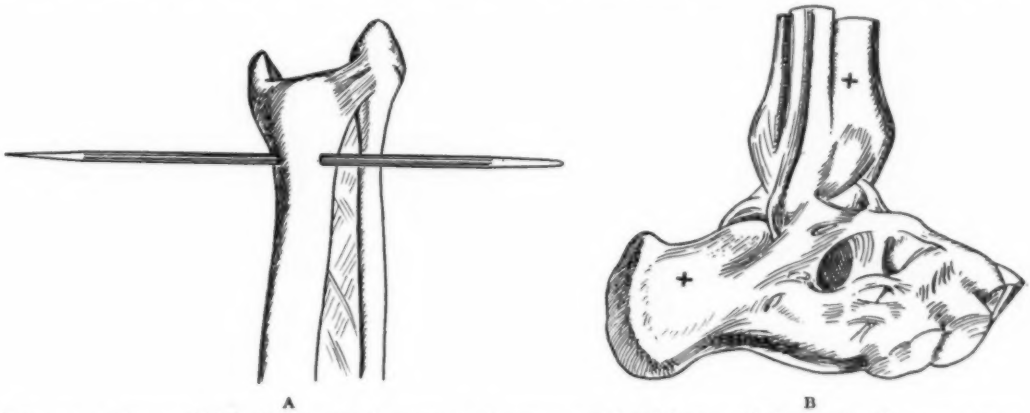
Dressings. Small gauze squares should cover the skin at the points of emergence. A small amount of thymol iodide (aristol) over which some collodion is poured, covered by gauze, helps to keep down the growth of skin organisms. A bandage fastens the gauze dressings in place. In children and neurotic adults, voluminous dressings covering the entire site of skeletal traction are advisable, to prevent the patients from knowing that the limb is transfixed.

Side Slip. At first the nail or wire is firmly fixed in its bony canal, but as time goes on it may become more or less movable. If traction is perfectly straight (axial), there is no tendency for the transfixing metal to move from its original site. However, if there is a marked tendency towards rotary displacement or angulation, and if a diagonal pull directly to the traction apparatus is used to correct this, the transfixing nail or wire tends to move either inwards or outwards, depending on circumstances. This, in turn, is apt to lead to infection of the nail or wire tract.

To prevent such side-to-side movement, various means have been devised. Klapp and Block use a figure-of-eight bandage, the loops of which include the opposite sides of the limb and the arm of the horseshoe clamp. They also employ a varying number of felt discs transfixed by the wire, to take up all space between the skin and the limbs of the horseshoe spreader is taken up. Other authors clamp metal discs on the wire at its points of emergence. Obviously none of these methods is absolutely certain in its result because the soft parts are elastic.

Attachment of Traction. As has been indicated, the Steinmann tongs and the rigid horseshoe-like Kirschner wire-holder are the most convenient methods of traction attachment. Where nail and tongs are used, traction should be made upon the ends of the crossed limbs, not at the point where they cross. (Fig. 1B and D.) This automatically keeps firm the contact of the holder with the projecting ends of the nail.

In cases where such appliances are not available, all sorts of apparatus may be improvised provided the desired mechanical effect is attained. (The Kirschner apparatus has been described above.)



A B

Fig. 12. A, lower tibial site of attachment. In fractures of both bones of the leg in the upper two-thirds, the transfixion point is through the *tibia only*, two fingers' breadth above the ankle joint or three fingers' breadth above the internal malleolus. B, attachment to os calcis. For fractures of both bones of the leg just above the ankle, the nail or wire transfixes the calcaneus one and one-half fingers' breadth below and behind the malleoli. The cross on the lower tibia marks the lower tibial site of attachment. (*After Steinmann.*)

Anesthesia. For patients in shock or in those of a distinctly phlegmatic nature, *local anesthesia* down to the periosteum on both sides may be employed. Boehler and others advocate injecting local anesthetic solutions into the fracture hematoma as well, in order to produce relaxation at the time when skeletal traction is initiated.

The author, however, prefers a *brief general anesthesia*, induced after everything has been prepared for the application and adjustment of skeletal traction. The patient then wakes up to find his limb in traction suspension and feels far more comfortable than before the induction of the anesthesia. Moreover, in certain nervous patients the realization that a limb is being transfixed by a steel object may be disastrous to morale. After traction and suspension have been applied, and while the patient is still unconscious, manual correction of lateral displacement is often possible.

Correction of Displacements by Traction and Suspension. The amount of traction varies according to circumstances. A good initial criterion is to pull upon the line of traction, and, sighting along the limb, to see whether any sag in the limb is corrected by the additional pull. If such a sag exists, additional weights sufficient to remove the sag are provided (except in very obese or extremely asthenic subjects). In addition, padded slings beneath the thigh and leg, with wooden battens to keep them from narrowing (Fig. 10), if properly counterbalanced, usually prevent posterior angulation.

A tendency to external rotation is controlled by suspension with cord or flexible wire, attached to the outer end of the nail or wire and led to the overhead frame. (Fig. 10.) Foot drop is prevented by applying one or two pounds suspension to a suitably shaped adhesive plaster slipper (Fig. 10) or a stockinet sock glued in place with mastisol.

The method just described is simpler, easier to improvise and often just as effective as the more complicated ones using Thomas splints with Pierson leg pieces or Braun or Boehler frames, etc. However, these must be kept in mind for special cases.

In speaking of traction suspension treatment of fractures, including both skin traction methods and skeletal traction, Kennedy correctly states:[7] "The aim in an early case should be to restore normal

length of the extremity in not over six to twelve hours after traction is applied. . . . If, after twelve hours, shortening has not been corrected, either the wrong method of traction has been used or too little weight has been applied." He adds that the amount of weight to be used "depends on the site of the fracture, the amount of muscle damage, the time after fracture elapsing before skeletal traction is applied, the weight and muscular development of the patient. Fractures in the upper parts of the femur and leg require less weight than fractures lower down in these bones. . . . For example, fractures with badly torn musculature, often compounded, require less weight than those with relatively intact muscles. . . . Any extremity can be restored to its original length by (various) traction methods, skeletal if skin (traction) is not effective, if union has not taken place. . . . Twenty-five to 30 pounds of skeletal traction is not unusual at the start of treatment of a fractured femur. . . . In general, traction by adhesive plaster requires twice as much weight as skeletal traction to produce the same effect." Conversely, skeletal traction is about twice as effective as skin traction in recent cases.

In fractures several days or several weeks old with much shortening, skin traction will not overcome shortening, but *skeletal traction will.* Here, naturally, greater weights are used than in recent cases. (Up to 60 pounds have been used by the author.) Obviously, the longer a fracture of the long bone is left untreated before traction suspension is applied, the greater is the amount of weight required to obtain proper reduction.

In recent fractures "the principle is to apply sufficient weight to reduce over a short period and lessen weight gradually over a longer period. . . . When the patient still complains of pain at the site of fracture, the indications are to apply more weight rather than less." (Kennedy.[7])

Control of Fragments. Often lateral displacement, shortening and angulation are corrected upon application of effective traction. The fragments slide past one another and fall into line; the diameter of the limb lessens and circulation is improved.

In fractures of the upper third of the femoral shaft, the upper (uncontrollable) fragment is often in abduction and flexion. The lower (controllable) fragment consequently must be brought into line by following the upper's deviation until angulation is eliminated. Semiflexion of the knee at the same time produces optimal muscular relaxation.

Fractures at middle third of the femur usually fall into good alignment with adequate traction, and any posterior angulation (sagging) may be controlled by counterbalanced suspension. Semiflexion of the knee to afford muscular relaxation is advisable.

Supracondylar attachment of skeletal traction for fractures above the lower third of the thigh permits motion at the knee and the ankle, preserving function while the fracture is consolidating.

In transverse or oblique supracondylar femoral fractures, skeletal traction should be applied to the head of the tibia with the knee flexed to a right angle in order to lessen the pull of the gastrocnemii. Traction applied axially in the direction of the femoral shaft often corrects displacements of the short lower fragment. If not, additional pressure (leverage) in the popliteal space by means of a suitably placed pad on a Braun or Boehler splint may be required to correct the angulation.[6]

In T-fractures of the supracondylar region, shortening must first be overcome by skeletal traction on the tibial head (as described above) before the separated condyles are compressed. A suitably padded carpenter's or boat-maker's clamp may be used for compression reduction; position is then to be maintained by a plaster of paris cast.

The same principles apply to comminuted fractures of the tibial head with

shortening, *viz.*, apply traction and follow up with compression.

In fractures of both bones of the leg, the upper tibial fragment often impinges against the skin to produce anterior angulation. To correct this, *the distal fragment is elevated*, with the knee in semiflexion, i.e., the leg is maintained in a position horizontal to the bed with the knee flexed. The horizontally-placed leg must *not* rest on a flat surface. The supporting sling, webbing, or moulded plaster gutter or cast must afford a place for the prominence of the calf muscles, conforming thus to the shape of the limb. Pressure on the heel leads to decubitus. In fractures of the upper two-thirds of the leg, skeletal traction applied to the tibia above the ankle joint (see above) is effective and convenient. This permits free motion at ankle, an additional advantage. In fractures of both bones of the leg in its lower third skeletal traction is applied to the calcaneus.

Badly comminuted fractures of the ankle with spreading of fragments are treated by extension, followed by compression and immobilization in plaster, leaving fenestra for the exit points of the skeletal attachment.

The various forms of distraction apparatus with multiple sites of skeletal attachment (devised by Roger Anderson, Klapp and Block, and others) show to what refinements the method can be carried. (Figs. 5, 6 and 7.) Klapp and Block also show ingenious methods (Fig. 5) for lateral traction by wire, but these must be reserved for exceptional cases.

Measurement. It is extremely risky to depend upon external measurements alone. The pelvis invariably tilts toward the side to which traction has been applied and *unless the well limb is abducted on the pelvis to the same degree as the injured one*, measurements will be misleading. Even with such abduction one cannot be certain, as it is well known that variations in length of as much as ¾ inch may normally occur between the two lower extremities (measuring from the anterior superior spine to the internal malleolus). Consequently, if sufficient traction is applied to bring the limbs to an equal length, and the shorter extremity happened to be the fractured one, an overpull of ½ to ¾ inch may result, leading to delayed union.* An overpull of even a few hours' standing is not corrected by subsequent lessening of traction, but leads to delayed union.

X-ray control is, therefore, essential. How often control exposures should be made depends upon the exigencies of the case under consideration; common sense and experience are the best guides. Kennedy[6] correctly advises *x*-ray control at least every twenty-four hours until the desired position and amount of weight are attained and maintained. Thereafter, weekly *x*-ray examination is necessary until firm union is present.

Interposition of Soft Parts. If *x*-rays show fragments apparently touching, but there is no crepitus, one must always bear in mind the possibility of soft part interposition. Yet even if soft part interposition indicates open operation, skeletal traction need not be discarded. It is most useful for control of the lower fragment at the time of open reduction and may still be needed afterwards if no internal fixation is employed.

Absolute anatomic reduction is not essential in obtaining a satisfactory result. If there is neither shortening, angulation (either anterior-posteriorly or laterally), nor rotary displacement, it is wiser to leave well enough alone than to strive for absolute perfection and possibly make matters worse.

Consolidation. The presence or absence of callus in the *x*-ray does not prove that firm consolidation has taken place. Absence of false point of motion and absence

* The late Reginald Sayre, in a personal communication, stated that in the days before the *x*-ray, those surgeons who were most meticulous in their attention to fractures of the thigh which were treated with skin traction and suspension, and who were most assiduous in seeing that both limbs were made equal, had decidedly more cases of delayed union than had their less industrious brethren.

of pain at the site of fracture upon raising limb are, however, conclusive. The time of consolidation varies. When the shadow of bony callus makes its appearance, the fibrous callus palpable to the finger is much larger than the bony callus seen in the *x*-ray. Its size diminishes as time goes on, but not until the patient is able to raise his foot from the bed without assistance and without local pain, is it safe to consider letting him up on crutches. Before such a time, angulation at the site of fracture may be expected to develop.

Removal of Traction. Nails should not be kept in place longer than thirty to thirty-five days. If consolidation has not taken place by then some other form of retention must be substituted for skeletal traction. For example, in a fracture of the shaft of the femur, with skeletal traction still functioning, a plaster of paris spica is applied from pelvis to toes, leaving fenestra around projecting nail ends. The next day, when the plaster has dried, the cast is divided opposite the site of fracture and the two halves of the cast are distracted by turnbuckles (incorporated in the cast the day before) until everything is snug. A steel tape is put on stretch, well past the projecting nail end, with the upper end of the tape firmly pressed on the plaster spica over the anterior superior spine. As traction is released, the operator must note whether the nail end moves upwards, past the marks on the tape. If it does, more distraction is indicated; if not, then the nail may be removed.

In removing the nail, the point must first be exposed and cleaned of any crusts, dried secretions, etc., after which it and the nearby skin are liberally painted with iodine. The head of the nail is grasped by a strong pair of pliers and is withdrawn with a slow, rotary motion. The nail tract is flushed with tincture of iodine and an alcohol wet dressing is applied to nail holes for a few days until they close.

Wire traction may safely be left in place much longer than nail extension. Its removal is simple; after withdrawal of the tensor clamp and disinfection of the skin, a pair of sterile wire-cutting pliers is pressed against the skin sidewise, exposing part of the wire previously buried in the soft parts; this is then cut flush with the depressed skin, and the other end of the wire grasped and withdrawn. Dressings are applied to the points of emergence, which heal in a few days. Occasionally the thin bluish scar bulges afterwards, and when it is opened, a small amount of secretion with some exuberant granulation tissue is discharged. Healing again follows.

COMPLICATIONS OF SKELETAL TRACTION

Pain. Properly applied skeletal traction causes no pain at the site of attachment. However, pain may occur in the following circumstances.

1. *Pain at the site of attachment immediately after traction is applied* indicates pressure on the soft parts by the nail or wire, distal to point of emergence. This is especially likely in the supracondylar region when an assistant has failed to pull upwards (cephalad) on the skin and soft parts just before and all during the period of transfixion. If this occurs, immediate correction is necessary, since unrelieved pressure results inevitably in necrosis of the skin followed by infection of the tract. If a nail has been used, it should be withdrawn and re-inserted correctly at some other point. The taut wire, however, need not be removed. Instead, a sharp bistoury is used to cut the skin in the direction of the pull until all pressure is relieved. The wire is now at the lower angle of a small longitudinal wound which heals of itself without suture—circulation has been restored and pain has been relieved.

Traction applied to upper margin of the calcaneus by nail, wire or Finochietto stirrup, may press upon the periosteum and cause constant pain, but this is not the case when the calcaneus is properly transfixed.

2. *Pain occurring later,* i.e., days or weeks after skeletal attachment, merits

immediate investigation. Infection is usually present. (For treatment see below.)

3. *Pain upon withdrawal* of the nail or wire is so negligible that anesthesia is not indicated except in extremely neurotic subjects.

4. *Pain at the site of fracture* is relieved by traction. The more effective the traction, the more comfortable the patient.

5. *Pain at any point of the limb* other than the site of fracture is evidence of improper adjustment of balanced suspension. This is to be investigated and immediately corrected, as otherwise decubitus usually results.

Infection. 1. *At the time of insertion* infection is due to either lack of asepsis or failure to avoid penetration of the fracture haematoma.*

2. *Infection occurring later* is usually due to overlong retention. Nails should not be left in place more than thirty to thirty-five days. After this time they are likely to induce infection and persistent bone sinuses. Kirschner wires have proven far less irritating to both soft parts and bone, and their proponents claim that they may be left in place almost indefinitely.† Should infection occur, it is wiser to reapply skeletal traction at another point through healthy tissues before removing the original nail or wire. Klapp and Block suggest first irrigating the wire tract with rivanol to control infection. If only one side is affected and removal is indicated, remove wire drawing it out from infected side. The surgeon must be guided on the whole by the severity and extent of the infection and use proper means for controlling it.

Infection some time after insertion is also apt to be caused by a gradual shifting of the wire (or nail), either lateral or mesial, along its tract. This is especially prone to occur when leverage is applied to the transfixion apparatus in addition to the customary straight axial pull, in order to correct angulation. Prevention of such lateral shifting by padding with discs of felt, metal discs clamped to the wire (or nail), bandaging, etc., have been mentioned above. Fatal infections may originate from the attachment points of skeletal traction.

Injury. 1. Injury to the *nerves or vessels* can only occur if anatomic landmarks are ignored or obscured by voluminous drapings at the time of insertion. There has been no recorded injury to muscles, motor nerves or vessels by skeletal traction per se up to 60 pounds.

2. Injury to *Bone.* As already indicated, wire is tolerated by bone for a much longer time than the bulkier nail. Only in the presence of infection does bony tissue soften, permitting gradual cutting of the wire in the direction of the axial pull. In children the points of transfixion must be well away from epiphyseal lines; if too close to these, the wire is apt to cut through the bone and inflict severe damage to the epiphyses, with attendant evil effects both immediately and later. The os calcis has been cut through from the point of transfixion to its lower (plantar) surface, but this is exceptional. Probably there was rarefaction from disuse.

3. Injury to *joints*, especially the production of lax knee joints, was raised as one of the objections to skeletal traction at the time of its introduction, but experience has shown that this does not occur in the treatment of recent supracondylar fractures of the femur before appreciable consolidation has taken place. However, the contingency of a lax knee joint must be kept in mind with the excessive traction which must be used in very late cases of this sort. Injury to the ankle joint by

* See Steinmann's original criteria cited in the text above. Fatalities have been known to follow infections due to the penetration of fracture hematomas by nails or wires, although certain authors report success with methods which ignore this rule. Presumably this merely indicates their good luck.

† As a high record Block and Klapp[3] cite a case in which wire traction was applied to the os calcis for 197 days without infection or necrosis of the bone. The subject was a woman of 32 with a chondrosarcoma in the upper end of tibia, for which resection of the knee joint was performed. Local recurrence was followed by amputation. Examination of the bone and soft parts in which the wire had lain for this length of time showed no infection and slight connective tissue reaction.

skeletal traction is not mentioned in the literature so far as the author knows.

4. *Overpull and Delayed Union.* In recent transverse fractures Klapp and Block, Boehler and others advocate a momentary overpull to permit end-to-end coaptation of fragments by manipulation under the fluoroscope. This is desirable if it is feasible.

Overpull, that is, distraction of fragments with an appreciable gap between, is almost impossible to correct if it is allowed to exist longer than a few hours. Delay in union is bound to occur. (Kennedy[7] and Blum[8]). Overpull is more likely to cause trouble with transverse than with long oblique fractures. However, overpull is rarer than underpull.

ADVANTAGES

Weight Requirement. Because of its effectiveness, skeletal traction requires about half as much weight as that needed for skin traction under like conditions, and yet with skeletal traction more weight can safely be used. Skeletal traction is safer than plaster of paris casts in assuring maintenance of reduction.

Painlessness. Properly applied skeletal traction should cause no pain at the *site of attachment.* The more effective the pull, the less discomfort at the site of fracture. Pain elsewhere means improper application of balanced suspension.

Control of Fragments. It is the best method for this purpose except reduction at open operation.

The small site of attachment makes skeletal traction available in the presence of compound fractures or simple fractures with extensive abrasions, where skin traction or plaster of paris casts are contraindicated.

Accessibility to daily inspection and ready adjustment are great advantages of this method.

Preservation of Function at Joints. The maintenance of joint functions, especially in fractures of the thigh with supracondylar skeletal attachment, is of decided advantage.

Simplicity and the possibility of improvisation with materials at hand make the method available on shipboard, in lumber camps, mines and similar localities remote from hospital centers, at the same time rendering transportation to hospitals safer and less painful.

Results with skeletal traction are excellent, when the method is employed by those properly qualified through training and experience.

COMMENTS

Certain over-enthusiastic advocates of skeletal traction and distraction use it in cases where the older time-honored methods would do just as well.* Others, probably on economic grounds, seem overanxious to make their patients ambulant at the earliest possible moment. The author advises "playing safe" unless it is absolutely certain that patients who are ambulant, can be under constant supervision and definite control. In a large metropolitan center, patients once discharged from the hospital, for some reason sufficient unto themselves, often fail to return; then weeks later they apply for treatment at some other institution with angulation and other untoward sequelae. This is especially true of children and less intelligent adults.

Skeletal Control in Fractures of the Patella. Several types of apparatus have been devised to approximate the separated fragments in fractures of the patella produced by indirect violence. This idea is

* For example, I may cite the case of a woman with flaccid muscles who sustained a fracture of the shaft of the humerus at the middle third. Two Roger Anderson pins at an angle to each other were inserted into the shaft and greater tuberosity, and a third pin was passed transversely through the olecranon. Absolute anatomic reduction of the fragments was immediately obtained and the pins were fixed in place by a plaster of paris cast for ten weeks. The elbow was stiff, there was delayed union of the fracture and two keloid scars in the shoulder "marked the spot." Had this patient been put to bed in balanced suspension with skin traction, her shoulder and elbow would be free and the chances of union would have been infinitely better.

basically unsound because a piece of torn quadriceps fascia usually covers the face of the upper fragment's fractured surface. Consequently, this interposed soft part certainly prevents bony union, no matter how closely the two fragments are brought together. Furthermore, such approximation by wires or pins does not make provisions for repairing the transverse tears in the lateral expansions of the quadriceps fascia to either side of the broken sesamoid patella, which is, in fact, even more essential than the accurate approximation of the bony fragments.

INDICATIONS FOR SKELETAL TRACTION

1. *Immediately after fracture*, where balanced suspension with skin traction or plaster of paris is contra-indicated skeletal traction should be employed. This is especially desirable where circulation beyond the site of the fracture is impaired through pressure on the vessels by displaced fragments, as, for example, in certain supracondylar fractures of the femur.

2. *Several days or even weeks after fracture has occurred*, and before consolidation has taken place, skeletal traction is the method of choice. Shortening has been overcome as late as forty days after fracture.

In patients with such extensive abrasions that skeletal traction cannot be immediately applied, it may be wise to wait until abrasions have healed before applying skeletal traction. In patients developing delirium tremens skeletal traction should be delayed until the delirium has passed.

In the event of soft part interposition, skeletal traction should not be removed until after open reduction has been concluded (See above).

3. *In old malunions* with much shortening, skeletal traction is the only effective method available. The malunited bones are divided (the direction of division depending on whether the original fracture line was transverse or oblique) and their surfaces freshened. Shortenings up to 11 cms. have been overcome.

CONCLUSIONS

1. Skeletal traction is not to be employed where simpler methods will accomplish the same purpose.

2. Skeletal traction is particularly indicated and effective where skin traction and plaster of paris casts cannot or should not be employed.

3. It is the method of choice in avoiding open operation for reduction wherever possible, and is especially advisable in fractures of several days' or weeks' standing before consolidation has taken place.

4. In old malunions with much shortening, skeletal traction combined with operation re-establishing the original fracture is the only method safely and effectively to produce the necessary lengthening of the shortened limb.

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FRACTURES OF THE PATELLA

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THE patella is an especially vulnerable bone, partly because of its exposed position just under the skin of the knee, and partly because it is subjected to great leverage over the fulcrum of the femoral condyles. The bone enjoys the distinction of being the largest sesamoid in the body, and is also the *sine qua non* of the extensor mechanism of the knee. Although fractures of the patella are frequent and have interested the medical profession for over two hundred years, still didactic textbooks often leave many questions unanswered in the mind of the average surgeon who is responsible for the treatment of the individual case. Nearly every surgeon nowadays has seen a fracture of the patella treated during his interneship, and, if he has been fortunate, he has seen several—each perhaps treated in a different way. When confronted with the responsibility of his own case, he often would like to know whether the treatment should be conservative or operative. If conservative, what is the best method; if operative, what is the best incision, the best method of suture, the best suture material, the best means of fixation, when to mobilize, and when to permit weight bearing. After answering such questions for his confrères for many years and after treating a large number of these fractures by various methods, the author has some fairly definite suggestions to offer regarding treatment.

INCIDENCE AND ETIOLOGY

Fractures of the patella are generally seen in adults between the ages of 20 and 50; they rarely occur in adolescents and never in children. Whether the bone is broken by direct violence against the dashboard of an automobile, or by the indirect violence of severe muscular contraction to save a fall, is of little importance to the surgeon, because in the average case the fracture probably results from a combination of impact *and* violent muscular contraction. The type of fracture *is* of importance, however, because it determines the method of treatment necessary to restore the extensor apparatus of the knee.

PATHOLOGY

Nearly all fractures of the patella enter the knee joint with hemorrhage into the joint and a variable amount of injury to the surrounding soft parts. Usually the patella is fractured transversely and frequently is comminuted. With severe violence there is more comminution, and, because the distal fragment is anchored to the tibia by the ligamentum teres and the proximal fragment is pulled upward by the quadriceps, tears occur in the lateral expansions of the quadriceps. These tears in the quadriceps expansions of the capsule are very important, for they may extend laterally as far as the lateral ligaments of the knee joint. The torn anterior fibers of the quadriceps, with the periosteum, may fall into the fissure between the bony fragments and produce a fibrous union or a non-union. The amount of separation of the fragments is dependent upon the extent of tearing of the lateral expansions of the quadriceps as Key and Conwell[1] have explained, and without tearing of this lateral aponeurosis there is very little displacement.

Fractures without displacement or separation of the fragments are usually fissures of the bone or chip-fractures of its apex or margins. Vertical, or longitudinal, fractures *do* occur, however, and are often overlooked because of no apparent displacement. Lapidus[2] has recently called attention to this type of fracture, and Speed has reminded us that "although

longitudinal fractures usually involve the outer portion of the bone, the outer fragment *may* be displaced outward by the pull of the vastus externus." *X*-rays, using the technique described by Lapidus with the knee flexed, are needed to reveal such fractures. Böhler[3] has called attention to star-shaped fractures, produced by direct violence and attended with great comminution and derangement of fragments but without much separation. The important practical point is whether or not there is separation of the fragments.

DIAGNOSIS

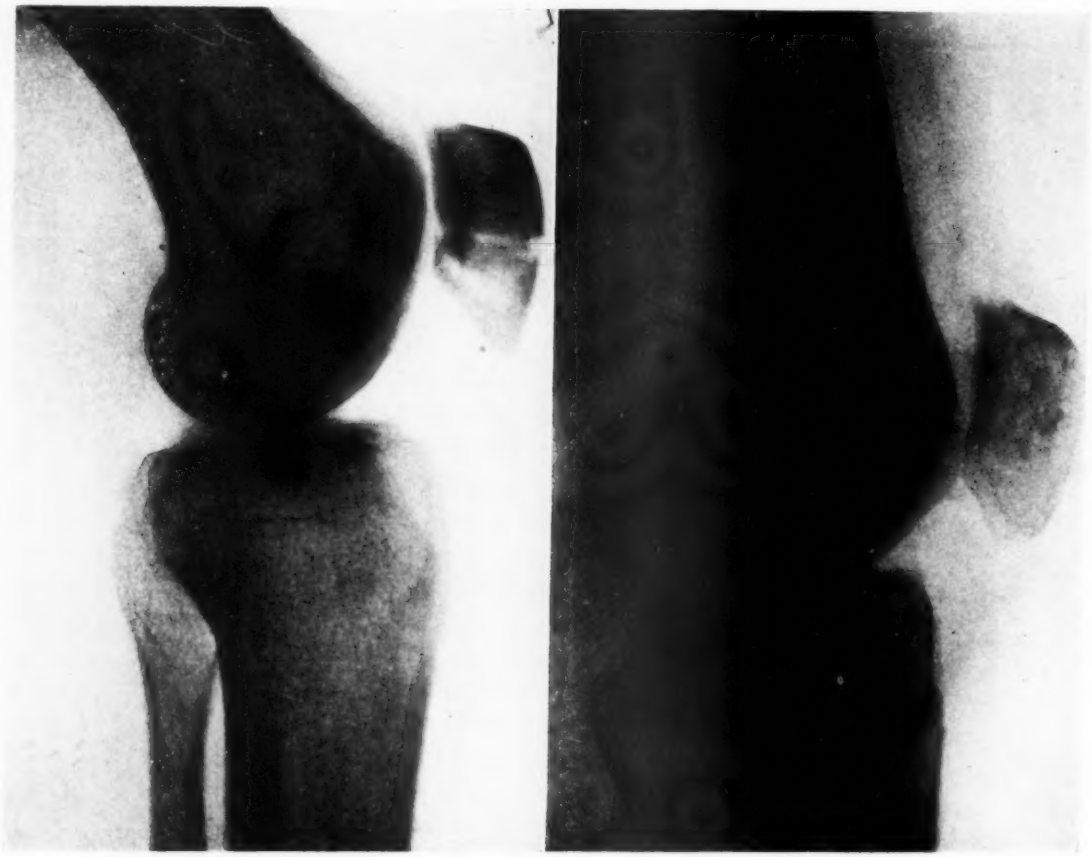
The diagnosis of fractures of the patella is usually easy. There is a history of a fall, or of an automobile collision, with resultant inability to extend the knee. The old diagnostic test of attempting to walk should be abandoned. Sometimes the patient *can* walk, with the knee hyperextended, only to have it give way during the test and increase the quadriceps tear. Dreyer's test, extension of the knee with the thigh extended, is only possible in fractures of the patella if the quadriceps expansion is not torn. The history, the localized swelling and tenderness over the knee cap, the disability, and the frequently palpable sulcus between the fragments, all warrant *x*-ray study to confirm suspicion of fracture. *X*-rays, of course, are routine, and the vertical view taken with the knee flexed should be obtained in suspicious cases without separation demonstrable by the usual technique.

TREATMENT

The controversy on treatment of fractures of the patella has simmered down to employment of closed methods if there is no separation of fragments, and open methods if there is comminution and displacement, providing the patient is a reasonable surgical risk. The keynote of treatment, as Watson-Jones[4] stated, is "restoration of the extensor apparatus of the knee without impairment of flexion." In the simple cases, splints and casts have been used successfully since the earliest times. These do not suffice in cases with separation, and, in order to gain bony union, many ingenious methods have been devised. Screws and nails failed to hold, as did adhesive plaster dressings. External encerclage by leather or metal bands was likewise found to be inefficient or produced ulceration of the skin. Malgaigne devised a clamp for skeletal traction applied by pins through the skin, and Ollier, according to Böhler,[3] inserted metal pegs and screws which were fastened together externally. Such methods seldom obtained bony union, because they did not remove soft parts intervening between separated fragments, and they have been abandoned.

Lister, in 1877, was the first to operate upon fractures of the patella, thus bringing this fracture into the field of open reduction ahead of all others. Lister sutured the fragments with wire, but found that the wire gave way unless the tears in the aponeurosis were carefully repaired. Failure to heed this experience of Lister's is to invite refracture. The late Prof. Schanz of Dresden was fond of presenting his guests with a specimen of bone some six inches in diameter for diagnosis. Bits of wire protruding from the specimen were the clue to the diagnosis of a fractured patella which Schanz was pleased to explain had suffered refracture twenty-seven times. The development of aseptic surgical technique gave impetus to the open methods of treatment and catgut, linen, braided silk, kangaroo tendon, and all kinds of wire have been employed for suture of the bone. Phemister in 1915 first employed fascia lata for suturing the bone, and Gallie in 1925 improved upon the method. Ober[5] recently recommended turning down strips of quadriceps tendon for suture material, and nearly every orthopedic surgeon now has his own favorite modification, as Allen[6] has reported. Watson-Jones[4] has reminded us, however, that "attention should be focused on *restoration of function*, not on repair of injury alone."

Conservative Treatment. Closed methods of treatment should be employed in cases of fissures, marginal fractures without displacement, and comminuted fractures without separation. Approximately one-third of all cases fall in this group and good results *can* be obtained by proper closed methods in such cases. (Figs. 1A, 1B.) If there is marked swelling and effusion in the suprapatellar pouch, it should be aspirated under strict aseptic precautions. Long adhesive straps should be applied crisscrossing above the proximal fragment to hold it down in close contact with the distal fragment. A properly shaped splint, extending from the gluteal fold to the tips of the toes, should be snugly bandaged on, with padding beneath the heel. A compression bandage may be added over the knee joint anteriorly to control effusion, but this is also controlled by elevation of the extremity. Many feel that fractures of the patella should always be kept in bed with the extremity elevated in order to relax the pull of the rectus femoris muscle, one head of which takes origin above the hip joint and is relaxed only in flexion of the hip.



A B

FIG. 1. A, transverse fracture without displacement. B, same fracture. Bony union by closed method.

The surgeon who can handle plaster of Paris has a much more comfortable and efficient dressing at his command for treatment of these cases. After aspiration of the effusion, long crisscross adhesive strapping should be applied to help hold the proximal fragment down. The cast should be applied to the straight leg, over stockinette, with a band of felt padding about the malleoli, and sheet wadding at the top. No other padding is necessary, but the cast should be light, yet firm, and should extend from the malleoli to the tuber ischii.

Star-shaped fractures of the patella without much separation of the fragments can be handled in much the same manner.

After aspiration of the effusion, the fragments can be pressed into better position with the fingers. Sterile sponge rubber, held in place over the suprapatellar pouch by an Ace bandage, helps to control the effusion of the first twenty-four hours on a splint; then a plaster of Paris cylinder cast can be applied as described above, taking care to have the knee straight and the hip flexed during its application.

Kessler[7] states that "most cases with marked disability are treated by the closed method," due to fibrous union and subsequent stretching of the scar. This need not be the case, however, if closed methods are reserved for cases without separation and if careful attention is paid to the essential details of treatment. Perfect apposition of the fragments is necessary and must be maintained until bony union occurs. Usually the case without separation of fragments is best treated in a hospital, and immobilized in a splint or cylinder cast with the extremity elevated for at least four weeks. Exercises to contract the quadriceps can then be instituted to prevent the troublesome complication of quadriceps atrophy. Gentle flexion can be started passively in six or eight weeks, and, according to Cotton,[8] weight bearing is safe at twelve weeks. The author prefers to wait until *x*-rays demonstrate bony union before allowing weight bearing, unless he is certain that there has been no tearing of the lateral expansions of the quadriceps.

Open Reduction. The method of choice in doubtful cases or cases with separation of the fragments is certainly operative. Open methods permit removal of loose fragments and intervening soft parts, secure firm apposition of large fragments, and enable proper repair of soft-part injuries—all of which shorten the healing period, minimize atrophy, and reduce permanent disability. Operative treatment is not to be undertaken lightly, or without proper facilities, or by surgeons not familiar with the modern technique of joint surgery. The knee joint is the largest joint in the body, is the most prone to infection, and should be opened only under proper conditions for fear of complicating sepsis.

The optimum time for operation depends upon the general condition of the patient and the condition of the local skin. There is no reason for delaying operation if the skin of the knee is suitable, as Wilson and Cochrane advise, but, if there has been abrasion of the skin, one should postpone operation until it has healed. The skin should be carefully prepared for operation, and the author has found Naughton Dunn's suggestions as to skin preparation to be most satisfactory. First the extremity is carefully shaved from ankle to groin, then scrubbed with soap and water. Next, the above area is cleaned with ether, then iodized, the iodine removed with alcohol, and dry sterile dressings applied over night. The iodine preparation is repeated on the operating table as usual. The Putti tourniquet is used routinely.

A straight transverse incision *above* the kneeling surface is most useful and practical. The longitudinal incision often does not permit careful examination of the lateral aponeurosis, and the U-shaped, or inverted U-shaped incisions, cause more scar and frequently do not heal well at their apices. The straight incision over the center of the patella follows a skin crease and heals nicely, besides affording excellent exposure without unnecessary dissection. The cut skin edge should be iodized and carefully walled off with sterile towels. Strict non-touch, or instrumental technique, is unquestionably the best. On retracting the skin, the extent of the damage to the lateral expansions should be studied and loose fragments of bone and clots removed. Only sponges wrung out of saline should be used to swab articular surfaces or synovia, and there is no excuse for flushing the joint with saline. The tears in the lateral expansions should be retracted, and the synovia sutured with fine plain catgut. Chromic catgut is entirely satisfactory for suture of the aponeurosis, beginning at the lateral edge of the tear and suturing up to the patella on each side.

Mattress sutures are best for the aponeurosis which should be carefully sutured while the fragments of the patella are held approximated to each other by a clamp or sharp hook retractors in the hands of the assistant.

A B

Fig. 2. A, inadequate wiring. B, too difficult wiring. Four drill holes.

The manner of suturing the bony fragments is less important. Since the advent of rustless steel wire, the author has used it exclusively for bone suture; it is tough, yet pliable, and is so completely non-irritant that removal is unnecessary unless the twisted ends happen to prick the skin. Rustless steel wire U.S. gauge 21 (.033 inches) is best for women, and gauge 19 (.044 inches) for men. By passing this wire through the ligamentum patellae just under the apex of the bone, a secure, firm grip on the distal fragment can be had extra-articularly away from the cartilaginous joint surface. Similarly, the wire can be passed through the quadriceps tendon around the base of the proximal fragment. The wire must be "snugged up" and twisted tightly enough to maintain close apposition of the fragments in this encerclage; then the twisted ends should be tamped down alongside the bone to avoid pricking the skin. Heavy braided silk may be used if rustless steel wire is not available. No soft tissue should be allowed to intervene, and close apposition of fresh, raw surfaces of bone to bone must be maintained. If the wire is too fine, it may break, and, if it is not drawn up tightly, it is entirely inadequate. Figure 2A illustrates inadequate wiring but with bony union due to proper suture of aponeurosis. At this point one should pause and test the integrity of the repair by flexing the knee through ninety degrees. Sometimes the encerclage, if not precisely placed, tilts the fragments, and a transverse drill hole may be necessary through the proximal frag-

ment to prevent this tilting. A smooth articular surface must be secured to avoid traumatic arthritic complications. Drilling requires more time, skill, and patience (Fig. 2B); too large a drillhole impairs the strength of the bone and favors refracture; small drills may break; also care must be exercised not to drill through into the articular surface. Catgut does not remain strong enough for suture of the bone, and it is difficult to get sutures of kangaroo tendon or fascia lata tied tightly enough to hold securely. In cases with a small distal or no distal fragment, Thomson[10] has successfully quilted kangaroo tendon through the ligamentum patellae, passed it proximally through two longitudinal drill holes in the proximal fragment, and sutured the ends of the kangaroo tendon together above the base of the proximal fragment. The subcutaneous fat and fascia are closed routinely with fine plain catgut, and the skin is closed with Dermal without drainage. Watson-Jones[4] feels that the "operative fixation should be sufficiently firm to make post-operative fixation unnecessary," and he employs only a compression bandage. A well-fitting plaster of Paris cylinder cast applied post-operatively adds to the comfort of the patient and the peace of mind of the surgeon. The skin sutures should be removed in two weeks, and then a new close-fitting cylinder cast applied as described above; then walking may be allowed with the aid of a cane. In Allen's[6] series the operated cases averaged forty days hospitalization, but less than three weeks are usually needed by the above method.

A B

Fig. 3. A, vertical fracture. B, results of multiple refracture.

Early walking prevents quadriceps atrophy and eliminates much physiotherapy. The second cast should be bivalved in four weeks (six weeks post-operative) and *x*-rays taken to check the progress of bone healing. Passive motions can usually be started at the end of six weeks, using the fingers to hold down the patella during the first passive flexions. Massage is best em-

ployed to *teach* active motion and active quadriceps contractions. The bivalved cast should be re-applied with straps for

A B

FIG. 4. A, weakening by too large drill hole. B, same after encerclage for refracture through too large drill hole.

night use and for protection in walking for another month, or until *x*-rays reveal goob bony union. Usually the patient has regained ninety degrees of flexion by the twelfth post-operative week, and then protection can be discarded. Recovery is not complete until the power of the quadriceps muscle has been fully restored, and the patient's activity should be guarded until this power has been regained.

Temporary total disability is therefore usually twelve weeks, as Kessler[7] reported, but permanent partial disability cannot be accurately estimated in less than six months. The condition is usually stationary at the end of six months, and any permanent partial disability existing at that time is usually due to fibrous union, restricted motion, quadriceps weakness, or arthritic changes.

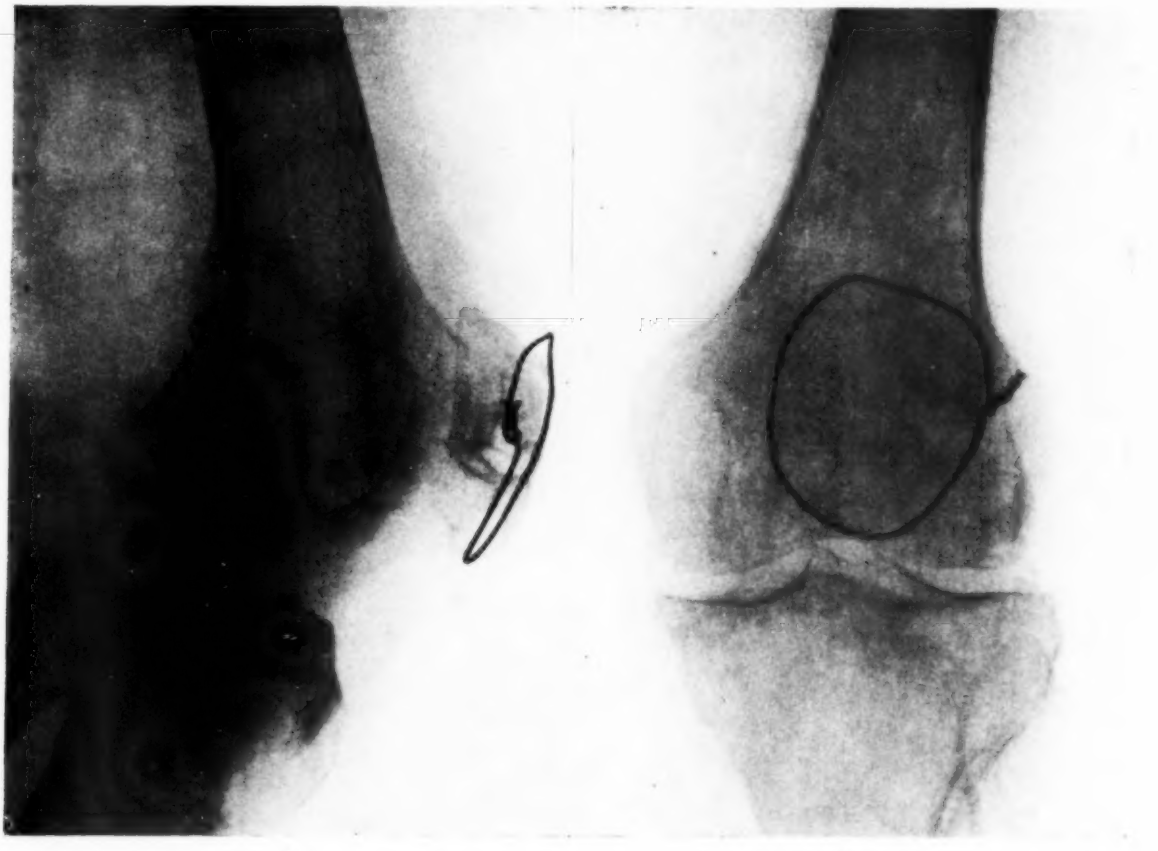
Compound fractures require a longer healing period and somewhat different treatment. They should be debrided, cleaned, and the skin sutured, leaving a small anchored drain. The joint should not be flnshed with saline as flushing may disseminate infection. Orr's principles of treating infected wounds are especially applicable in these cases. Rest, in a proper splint or cast, is indicated for two or three weeks, or until the skin has healed; then the fracture should be opened as described above, and the aponeurosis and bone sutured.

Infected fractures should be treated in the same manner, incising abscesses, cleaning the wound, but not washing the joint, and then immobilizing in plaster until the infection has subsided.

REFRACTURE

The patella is refractured oftener than any bone in the body, and this is the

greatest danger in treating these cases, whether by open or closed methods. (Schanz had a specimen that had refractured twenty-seven times.) Refracture leads to enlargement of the bone (Fig. 3B), elongation of the extensor mechanism with quadriceps atrophy, arthritis, and much permanent partial disability. The second fracture may be through the site of the original injury, as reported by Wilson,[11] or it may be through a drill hole (Figs. 4A and 4B), or through another portion of the atrophic bone. It most commonly occurs between the sixth and eighth weeks but may occur months after the original fracture. The chance of refracture, as Cotton[8] has emphasized, is greatest in the rigid knee in which adhesions have developed, but refracture rarely occurs after sixty degrees of active motion have been regained. With good operative repair, it is also unlikely, as Hawley's[12] figures have shown. Barring a second accident and unusual bone atrophy, refracture in most instances is secondary to some error in treatment. In order to avoid this unpleasant complication and other disabling sequelae, the important factors in treatment are summarized herewith as possible errors in treatment.



A B

FIG. 5. A, close apposition of fragments after encerclage. B, anteroposterior view of same. Encerclage with rustless steel wire.

POSSIBLE ERRORS IN TREATMENT

1. Inefficient splinting: splint too long or too short, poorly shaped, omission of padding heel, bandage too tight or too loose.

2. Inefficient plaster of Paris cast: cast too short or too weak or too heavily padded, omission of padding at top and bottom, cast applied with knee flexed; cast poorly fitting, dented or rough.

3. Failure to enforce rest in bed with extremity elevated in closed cases.

4. Open reduction of cases without separation or of star-shaped fractures.

5. Closed reduction of cases with separation of fragments.

6. Operation without proper skin preparation.

7. Operation without proper facilities and without a proper tourniquet.

8. Operation by those not familiar with modern joint surgery.

9. Use of longitudinal or U-shaped incisions.

10. Failure to remove clots, loose fragments, and intervening soft parts.

11. Failure to suture lateral aponeurosis securely.

12. Failure to suture bony fragments with reliable suture material.

13. Failure to secure close apposition of bony fragments.

14. Failure to restore a smooth articular surface.

15. Immobilization for too short a period.

16. Immobilization for too long a period.

17. Omission of passive motion to restore motion and prevent adhesions.

18. Omission of protection during period of restoration of joint motion.

19. Neglect of quadriceps atrophy.

20. Improper manipulation to forcibly restore motion.

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OSTEOCHONDRITIS DISSECANS

DESCRIPTION OF THE STAGES OF THE CONDITION AND ITS PROBABLE TRAUMATIC ETIOLOGY

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ALL discussions of osteochondritis dissecans are invariably prefaced by two basic considerations. The first of these is the confusion and disagreement existing with regard to the mode of onset of the condition. The second feature is the relationship of the etiology to trauma.

The different theories of causation have given rise to the multitude of descriptive terms used. To those who deny its traumatic basis the condition is one of "Paget's quiet necrosis," "partial necrosis of the epiphysis" or "exfoliating osteochondritis." To their opponents the entity is a "subchondral fracture of the articular condyle" or "osteochondrolysis traumatica." Each of these terms is peculiarly applicable to a certain phase of a process, the final stage of which results in the formation of an intra-articular loose body.

To König, the lesion was a "dissecting osteochondritis" of the articular condyle. Certainly no more graphic term could be employed to portray the loosely adherent articular cartilage which is found about the excavated area of the condyle. It does appear to have been lifted off the underlying bone. This, however, is a gross pathologic term and again does not give any clue regarding the mode of origin of the process.

ETIOLOGY

Of the involved joints the knee joint cases comprise more than 85 per cent of the reported cases. The elbow joint is next in order but isolated cases have been reported in the ankle joint and in the metacarpo-phalangeal articulations. In the knee joint, the commonest site of excavation is the *medial* condyle of the femur. Next in order of frequency is the lateral condyle of the femur and lastly, the posterior articular face of the patella.

In our small series of knee joint cases which were followed up, these three variations are represented (see Chart 1). Inasmuch as most of our cases were those in which the knee joint was affected, we are arbitrarily confining our discussion to that particular joint.

In that articulation loose bodies may arise from three different sources:

1. The articular surfaces of the femur, patella and tibial head.
2. As osteophytic remnants from an osteoarthritis.
3. Following proliferative synovial membrane disease.

It is obvious that the first group interests us only in the problem of the etiology of osteochondritis dissecans.

There are two main groups of reasons offered for the appearance of these fragments; first, the traumatic explanation of their origin and secondly, the non-traumatic theories.

Traumatic explanation of origin

1. *Extra-articular trauma*
   a. Monro (1738), Reimar (1770), Haller (1776), Broca, and Ludblatt were convinced of the direct effect of trauma from the outside which resulted in the immediate appearance of loose bodies.
   b. Axhausen (1914) advanced the idea: "that as a result of impaction from the opposing articular surface, the blood vessels to the

part are damaged, either with or without partial fracture, according to the severity of the violence. This leads to necrosis of the area supplied by the damaged vessels and as a result there forms a zone of absorption resulting in gradual separation and eventual extrusion of the dead portion of the articular surface into the joint."

c. Hellstrom (1922) declared that, "joint mice in osteochondritis dissecans are the result of a subchondral impression fracture."

2. *Intra-articular trauma*

a. Barth advanced the idea that the loose fragments were due to a pull of the posterior cruciate ligament. This has been experimentally proven impossible and does not explain either the patellar fragments or pieces resulting from the opposite femoral condyle.

b. Freiberg postulated an impaction of the tibial spine on the intercondyloid ridge as a factor.

c. Kappis (1920) indicated that tangential and rotating forces may act on the convex condylar surfaces and fissure or partially detach portions of the articular ends.

Non-traumatic explanation of origin

1. *Embolism.* This explanation has been founded on the postulates that, first, mycotic-embolic closure of an epiphyseal artery may lead rapidly to epiphyseal necrosis; secondly, that

CHART I.

FOLLOW-UP CHART OF KNEE JOINT CASES

Patient	Age and Sex	Site	Number of Fragments	Treatment and Date	Post-operative Result	Follow-up Result	Trauma Preceding Injury
T. D.	25 Male	Lateral condyle of left femur—medial aspect	Multiple	Arthrotomy 10-2-31	Satisfactory at six months	7-8-37 Excellent	Yes
C. J.	23 Male	Medial condyle of left femur—internal aspect	Multiple	Arthrotomy 11-27-31	Complete restoration at six months	7-8-37 Excellent	No
J. N.	39 Male	Medial condyle of left femur—internal aspect	Multiple	Arthrotomy 10-31-31	Satisfactory at eighteen months	7-8-37 Excellent	No
A. S.	20 Male	Medial condyle of right femur—internal aspect	Multiple	Arthrotomy 12-14-31	Satisfactory at eighteen months	7-8-37 Excellent	Yes
G. M.	32 Male	Medial condyle of left femur—internal aspect	Multiple	Arthrotomy 3-24-32	Satisfactory at six months	7-8-37 Excellent	Yes
P. M.	52 Male	Medial condyle of right femur—internal aspect	Single	Arthrotomy 5-24-32	Complete restoration at five months	Patient died 1933	Yes
L. T.	17 Male	Patella posterior surface	Single	Arthrotomy 10-28-32	Satisfactory at six months	No follow-up obtained	Yes
H. F.	18 Male	Medial condyle of left femur—internal aspect	Multiple	Arthrotomy 6-24-35	Satisfactory at six months	7-8-37 Excellent	Yes

the bacteria deposited may be vanquished by the body so that an infection does not take place and the necrosis remains aseptic. Thirdly, the joint bodies may develop *in situ;* therefore, from the aseptic epiphyseal necrosis by a process of demarcation. Although the epiphyseal arteries are not terminal arteries in the anatomical sense, inasmuch as fine lateral connections may be demonstrated, still the anatomical findings do not prove that the functional capacity of these fine connections is sufficient to insure nutrition of the epiphyseal region following closure of the chief arterial trunk.

Observations in osseous tuberculosis seem to prove that the lateral connections do not suffice and that the epiphyseal arteries are "functional end arteries," and that if they are occluded there must be an interruption of nutrition in the area they supply. The tuberculous wedge-shaped necrosis in the lower epiphysis of the femur with its apex directed towards the diaphysis may very well correspond to a single epiphyseal vessel area.

2. *Bacterial Factor.* Knaggs,[32] in his conception of the "quiet necrosis of Paget," or, as he describes it, "necrosis without suppuration," believes that the initial lesion is a periostitis due, no doubt, to a microorganic infection of a very mild kind; probably staphylococcic in type. The infection invades the surface of the bone, but, owing to its feeble virulence, is speedily limited and fails to penetrate the deep surface of the compact bone. Granulation tissue developing under the periosteum and in the Haversian canals of the superficial layers causes compression of the vessels and interferes with the blood supply of the compact bone in its deeper parts. By itself, this would not be sufficient to cause death, if the blood supply to the interior of the bone were adequate. If, however, the nutrient canal is similarly invaded, compression of the artery will seriously curtail the supply of blood to the medulla and render the circulation within the bone unequal to the demands upon it. Thus the compact bone, being gradually deprived of its blood supply, or receiving an inadequate supply, slowly passes into a state of necrosis.

3. *Constitutional Disturbance Involving Bone.* This presupposes a congenital excessive brittleness in the epiphyseal bone which will account for the liability of a subchondral fracture.

After reviewing both the traumatic and the non-traumatic explanations, it is obvious that the traumatic theories per se are the more reasonable. Primarily they are bolstered by the facts that the condition is most frequently found in robust adolescents and adults actively engaged in vigorous pastimes. It is certainly more likely that this group would be subject to traumata than any other age group. The second striking fact presenting itself is the entire lack of suppuration. There is an absolute absence of any gross or microscopic inflammatory change in or about the lesion.

Thirdly, cultures which we prepared from excised tissue invariably were reported as showing no growth. Tissue was taken not only from the site of the lesion but from the synovial membrane lining the joint. At no time were there any bacteria found in specimens of the joint fluid.

Those who refuse to accept the absolute traumatic origin point out that in the majority of cases there is an absence of any history of trauma or definite injury. They also stress the insidious nature of the onset and the mildness of the early signs and symptoms. All these are totally inconsistent with the idea that the lesion is the result of a single definitive trauma, unless that original injury be a minor one. If the original trauma were a slight one it is

conceivable that its effects might be intensified and kept up by the continuance of such strain as vigorous exercise, weight bearing, or violent sports.

overlies. For this reason, the subchondral injury will be accompanied by little or no pain.

This lesion can be followed radiograph-

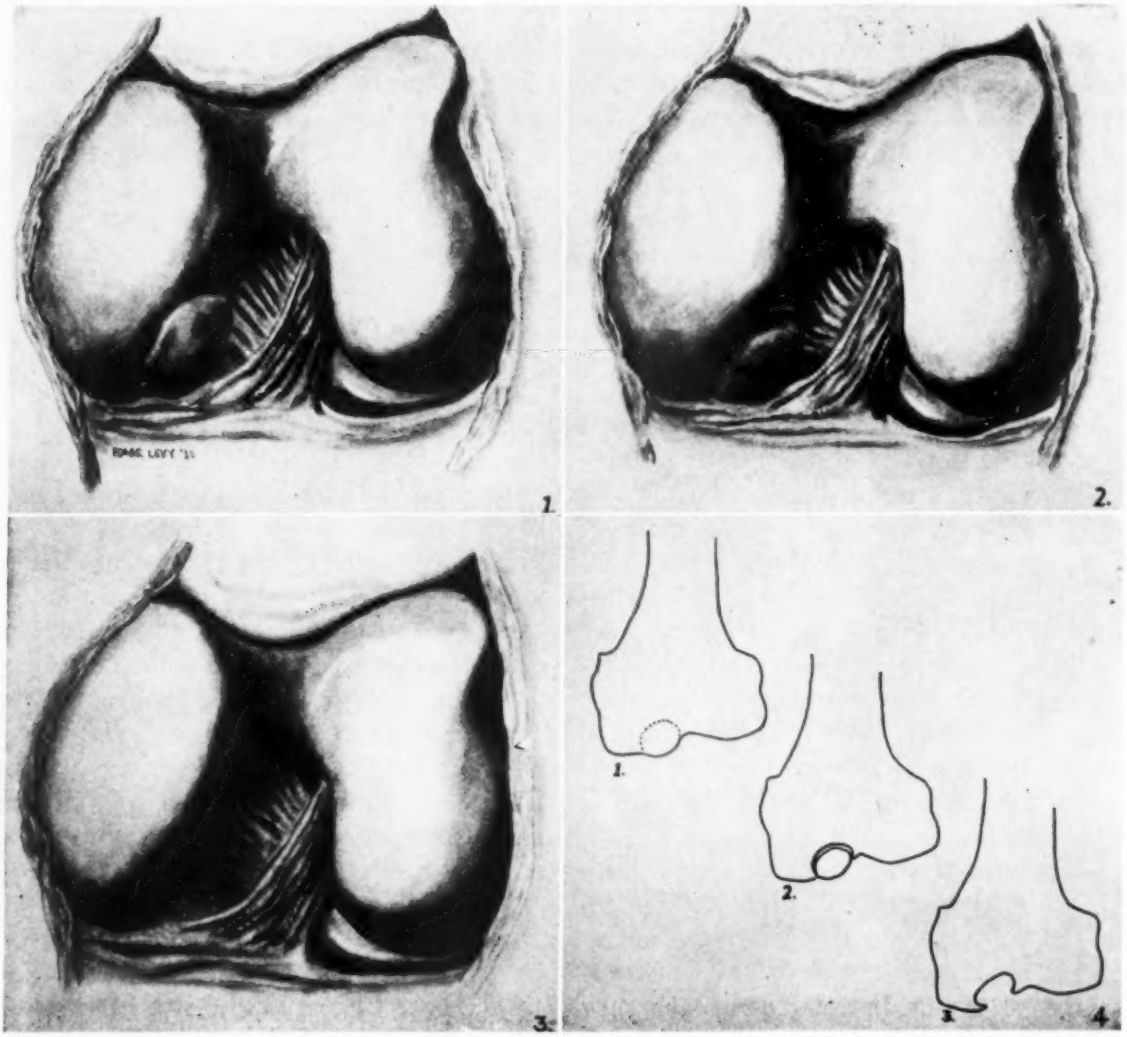

Fig. 1. This type of case shows a fairly well demarcated prominence of the articular surface. The articular cartilage covering this elevation is of a different color from the rest of the cartilaginous surface. (From Conway in *Ann. Surg.*, vol. 99, 1934.)

Fig. 2. At this stage in the process, the fragment has become more distinctly separated and lies within the excavated area, being held there by a small adhesion. (From Conway in *Ann. Surg.*, vol. 99, 1934.)

Fig. 3. The fragment has left the area in the articular surface and is wandering about freely within the joint. (From Conway in *Ann. Surg.*, vol. 99, 1934.)

Fig. 4. Schema showing the three stages of the process. (From Conway in *Ann. Surg.*, vol. 99, 1934.)

Now, a subchondral fracture per se is a minor injury and in the knee joint the stages of such a process following injury can be carefully watched. It is to be remembered that the articular cartilage is devoid of nerve supply and that there is very little sensation in the cancellous bone which it

ically up through the stage of loose body formation. (Figs. 2, 3, 4.)

It is many times frequently true that the patient's attention is not called to his condition until the process has reached the third stage of free loose body formation within the joint cavity.

When the third stage of the process is preceded by a trauma and a radiograph shows the loose fragment, many are ready to believe that that particular injury caused the loose body's presence in the joint. At operation, however, the arthrolith will be found to bear no sign of recent damage and the condylar bed from which it evolved is ofttimes already filled in with fibro-cartilage. It cannot be denied that its immediate liberation may have been due to the trauma but to attempt to predicate the entire process on that specific injury is without basis. Again, the use of such a case to substantiate the traumatic origin of osteochondritis dissecans is worthless for it is obvious that the process was of long standing.

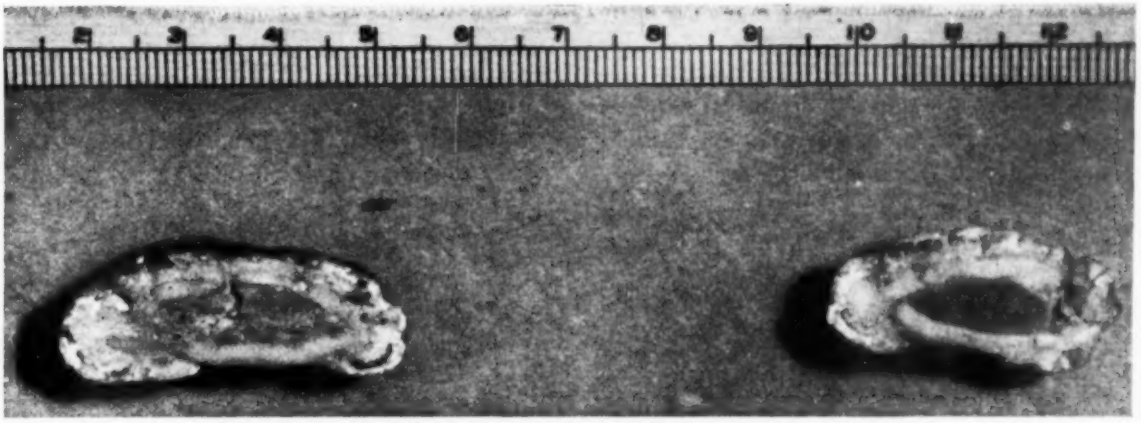

Fig. 5. Sagittal section of an arthrolith, indicating the lamellated character of the fragment as the result of the action of synovial deposition upon the original loose body. (From Conway in *Ann. Surg.*, vol. 99, 1934.)

In the femoral condyles and the humeral capitellum, the end stage of the process leads almost constantly to intra-articular loose body formation.

The roentgenographic appearances provide very startling evidence of bone changes which would appear to deserve more definite signs, symptoms and disability than actually occur.

Before leaving the question of etiology, attention should be brought to bear on the idea of the lesion being a simple subchondral fracture.

It is an accepted embryologic anatomical fact that as the articular epiphyseal centre reaches the periphery of its growth, there forms on its surface a thin layer of condensed bone to which the articular hyaline cartilage is affixed. The cartilage is devoid of nerve supply and the underlying bone, not having a periosteal coating, has a very slight nerve supply.

Traumata transmitted via the patella and acting through the cushion of the articular cartilage will fissure, split or chip off a piece from the condyle. Owing to the almost complete lack of nerve supply in the region of this fracture, there is little or no disability and so the original accident is forgotten and the process starts.

In the elbow joint the head of the radius is the transmitter of the force, a fall on the hand driving the radial head against the capitellum and causing the subchondral fracture.

In many cases, the actual liberation of the body appears to be due to some definite specific trauma such as a twist or strain, but examination of the loose body and its former bed will make it clear that the condition is, in reality, one of long duration.

PATHOLOGY

In a previous report[17] the pathological findings were described according to the various stages of the condition. Figures 1, 2, and 3 with the accompanying schema show the gross changes which occur.

In the first stage, there may be only a fairly well demarcated prominence of the articular surface with the articular cartilage covering this elevation of a different color than that of the rest of the cartilaginous surface. (Fig. 1.) If this prominence be excised during this period of the disease—and as a rule it is rather easily separated—a beginning excavation of the cancellous subchondral portion of the articular end of the bone may be observed. The ease with which this articular osseocartilaginous prominence may be removed is in striking contrast to the difficulty with which normal articular cartilage is removed from the end of any normal femoral articular surface.

The second stage in the process we recognize is one in which the fragment has become more distinctly separated and lies within the excavated area of the articular surface, being held, perhaps, by the merest shred or by a fairly firm adhesion. (Fig. 2.)

This fragment is easily removable; in fact, it may be merely lifted out of its bed. Surrounding this excavation, the articular cartilage is of a peculiar appearance, having an ivory-like cast, and in contrast with the normal articular cartilage it appears actually buff-colored. In addition to this color change, the cartilage is not firmly attached to the articular end of the underlying cancellous bone, but is easily removable for a varying distance from the sequestrated focus. The ease with which it may be lifted gives it the actual appearance of having been dissected off and this characteristic is expressed in the name "osteochondritis dissecans," which was first applied to this condition by König,[33] in 1887.

The third stage is merely the completion of the first two periods and is characterized by the complete sequestration of the fragment from its place on the articular surface into the joint cavity. The fragment may remain freely movable within the joint cavity, being bathed by the synovial fluid and become lamellated in structure by a process of accretion, or it may become affixed to the synovial wall of the joint. The excavated cavity presents of itself no distinctive features, being lined by a thin velvety layer of reddish-gray tissue. Curettings of these foci do not reveal any specific pathological picture which would indicate anything of a specific nature of the process. Cultures of the curettings removed at operation have shown no bacterial growth.

The excavation gradually becomes filled in with fibrocartilage and in outline becomes shallower and less pronounced.

The Fragment. Following the loosening of the fragment from the articular surface, degenerative and regenerative changes occur in it, both while it is attached by a pedicle and after it has been completely extruded within the joint.

While it is attached by a pedicle, it may be nourished through blood-vessels existent within the stalk of the pedicle and the degenerative changes in the fragment may be slight. However, both the articular bone and cartilage tend to a general necrosis. In some cases, the proliferative changes may be considerable during this period and in the microscopical sections evidences of osteoblastic formation may be seen. Principally, the proliferative changes consist in the formation of fibrocartilage along the surface of separation, but in the area where bone is present, there may be considerable new bone production. This proliferative process is most marked in the cancellous spaces along the zone of separation, and the old bone which becomes necrotic may be replaced by new bone.

After complete liberation within the joint, all bone which has had a blood vascular circulation becomes necrotic and there is still further necrosis and calcification in the articular cartilage. The fibrocartilage and the fibrous tissue along the surface of separation receive sufficient nutrition from the synovial fluid and proliferate, thus causing a slow but steady increase in the size of the loose body. The fibrocartilage gradually absorbs and

replaces the necrotic articular cartilage and less rapidly the necrotic bone, so that years after separation, the original constituents of the loose bony fragment may have completely disappeared. In many specimens removed from the joint, years after complete separation, a definite lamellation may be seen to have occurred and in one of our cases (P. M.), an arthrolith (Fig. 5) presents just such an appearance. A sagittal section through this body indicates the laying down of the lamellae around the original fragment. Concomitant with this laying down of fibrocartilage about the original particle, calcification occurs within the layers of the fibrocartilage and an extremely pathological type of new bone may be formed in its superficial portion. (P. M.)

The Synovial Membrane. With regard to the synovial membrane lining the joint, one may state that the character of it will depend upon the amount of irritation that has been offered to it as the result of trauma from the loose fragment or fragments, the extent of the hemarthrosis existent and the length of time these two factors have been present. Changes in the synovia from a simple edema of the synovial papillae to a pronounced hypertrophy of the individual and multiple single papillae which have been in direct contact with the offending loose fragment have been observed. The extent of this traumatic hypertrophic synovitis and its striking subsidence within a short interval following arthrotomy with the removal of the loose fragments is quite pronounced. With persistent trauma from the loose particles, joint changes of an osteoarthritic nature will result within the joint.

Chemical analyses were made of the synovial fluid in several of the cases but were not found to be of any especial import and for that reason the values obtained are not reproduced in this report.

As to the pathological grouping of loose bodies that appear in joints, the following outline has seemed to the author to be the most inclusive. It is inserted at this point with an idea of demonstrating the place given to the group included under the name of "osteochondritis dissecans" in its relation to other loose joint bodies.

Loose Bodies of Cartilage and Bone May Be Divided into Three Groups. Group I. Loose bodies occurring in connection with some more or less general pathological condition affecting the joint as:

a. Osteoarthritis. (1) Detached osteophytes. (2) Detached epi-articular ecchondroses as a result of lipping of patella.

b. Tabes dorsalis.

c. Tuberculosis of joint accompanied by necrotic caries.

d. Acute arthritis due to infection.

Group II. Loose bodies occurring in joints that are otherwise apparently normal:

a. Bodies having the microscopical and sometimes the macroscopical appearances of detached portions of the articular surfaces (osteochondritis dissecans).

b. Bodies derived from the intra-articular fibrocartilages.

c. Bodies formed from detached epiphyses not forming portions of an articulating area.

Group III. Synovial chondromata, laminated and non-laminated:

a. Single.

b. Multiple.

c. Diffuse.

In concluding the pathological discussion, the following summary serves to coordinate the several facts elaborated above:

1. The condition is more often seen in males than in females, and in the more robust.

2. Fragments may be: (a) *Recent detachments:* Where bone and cartilage are living and there are no proliferative changes in the articular cartilage. It is in these cases where there is no sign of any morbid process that the clinical evidence strongly supports the traumatic origin of this group.

(b) *Bodies whose sojourn in the joint has been longer:* Where the articular cartilage shows proliferative changes.

(c) *Where there is marked degree of cartilage proliferation.*

(d) *Where cartilage proliferation is excessive.*

(e) *Where cartilage proliferation is feeble.*

3. Commonest site is the knee; next is the elbow.

4. The condition is usually unilateral.

5. Bodies may be completely or incompletely detached or may acquire a secondary adhesion to the synovial membrane. When incompletely separated, they are usually attached by a hinge of articular cartilage to the margin of a defect or loss of substance on the articular surface which corresponds in size and shape to the loose body.

6. Their continued presence in a joint may bring about changes of an osteoarthritic nature.

SYMPTOMATOLOGY

The signs and symptoms at the onset are not very outstanding. There may be some ache after exercise; tenderness on pressure over the affected joint or some muscular spasm.

It is evident that the acute symptomatology will begin with what is actually the third stage of the condition—the period of free loose body formation within the joint.

Locking of the joint, traumatic synovitis and the attendant joint disability all follow in order with the wandering of the loose fragment.

The radiographic evidence is diagnostic at all stages of the process. In the first two stages it is amazing to see the amount of bone disorientation that is present with such few clinical signs or subjective symptoms.

TREATMENT

Arthrotomy with the removal of the loose fragments is the only procedure. It should be performed as soon as possible after the diagnosis is made in order to prevent the attendant synovitis and traumatic arthritis which will accompany the presence of long standing intra-articular loose bodies.

CONCLUSIONS

1. The condition of osteochondritis dissecans is discussed with especial reference to its relation to trauma.

2. The three stages in its development are again postulated and the gross pathology described.

3. The treatment is arthrotomy before appreciable traumatic synovitis or arthritis develop to any degree.

4. A follow-up chart of cases followed over five years is included and the results regarded as satisfactory.

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FRACTURES OF THE TIBIA INVOLVING THE KNEE JOINT

"BUMPER" OR "FENDER" FRACTURES

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FRACTURES in the upper end of the tibia may be caused by crushing injuries produced by indirect violence, such as falls on the feet, but in recent years this type of fracture has become much more frequent as a result of direct violence from automobile injuries. Fractures of this type have become so definitely related to the use of the automobile that Cubbins and his associates[1] in 1929 applied to them the expressive title of "bumper" fractures. In the same year, Cotton and Berg[2] coined the name "fender" fracture for the injury caused by the impact of the automobile against the outer aspect of the extended knee. Their definition read in part: "This is a fracture of the outer side of the tibial head produced by abduction of the leg forcibly enough to smash the external tuberosity against the fulcrum of the outer condyle of the femur."

Since 1929 automobiles have been constructed with lower bumpers and, as a result, the injuries very frequently involve the middle third of the shaft of the tibia. They are characterized by severe comminution and are often compound. Some authors[3,4] reserve the term, "bumper" fracture, for these fractures of the tibial shaft and the term, "fender" fracture, for the injuries involving the condyles of the tibia. The use of the term "bumper" fracture in this double sense, although possibly more accurate today, leads to some confusion. In this communication, I wish to discuss only fractures of the condyles of the tibia involving the knee joint, or, as the French writers express it, fractures of the tibial plateau.

Fractures of the condyles of the tibia exhibit a multitude of forms, but, for consideration of treatment, are probably best classified in the following three groups:

1. Fractures of the lateral condyle.
2. Fractures of the medial condyle.
3. Fractures of both condyles.

In practically every series[1,5,6,7,8] reported, fractures of the external tuberosity constituted by far the greater proportion of the cases. In our series of 20 cases, 15 were of the external condyle, 3 of the internal condyle, and 2 were of both condyles. It is my purpose to confine my remarks largely to the *fractures of the external condyle although the same principles are applicable to fractures of the internal condyle.* Many articles have been written on this subject, but there still persists considerable difference of opinion as to the most desirable method of treatment. I wish to discuss some of the problems involved and outline a plan of treatment that has aided us in procuring and maintaining a correction of the displaced fragments and preventing the knock-knee deformity which is so apt to occur unless treatment has been adequate.

The violence sustained is of the crushing type, and if severe, leaves the knee with a squashed, depressed, comminuted external tibial condyle. On examination, the most characteristic finding is the marked lateral instability of the joint, which permits the leg to be abducted on the thigh to a varying extent. The external and internal lateral ligaments usually remain intact, but may be torn if the injury is severe.

In spite of the many different methods of reduction, both open and closed, which have been devised, there is as yet no unanimity of opinion as to treatment. In principle, all methods seek to obtain

restoration of an even tibial articular surface and to correct the knock-knee deformity. Even with a minor amount of persistent depression of the external condyle, the knee will be forced into a valgus position when weight bearing is started, and the entire limb will be thrown out of proper alignment, with a resultant tendency to arthritic changes. The type of reduction adopted depends upon the exact nature of the fracture. To determine this accurately, it is necessary to have multiple roentgenograms, taken not only in the anteroposterior and lateral positions, but also at quarter angles. With the aid of these, the fracture may be classified in one of three groups according to the following simple scheme:

Group 1. Those in which the condyle has been displaced mainly in a lateral direction (spreading fracture).

Group 2. Those in which the condyle has been displaced mainly in a downward direction without extensive comminution (depression *en masse*).

Group 3. Those in which the condyle has been comminuted and depressed (depression with comminution).

In our earlier cases, particularly where there was marked comminution, subsequent roentgenograms would show to our chagrin that less correction resulted than we felt confident had been accomplished at operation. This was in all probability due, in spite of the strictest precautions, to the unavoidable handling of the limb while the cast was being applied. It can readily be appreciated that, if the limb is inadvertently brought into valgus by the assistant who holds it after replacement of the comminuted fragments, these fragments again become depressed by the condyle of the femur. Such an occurrence could easily change the outcome of an otherwise carefully planned operation. For that reason we have adopted the following technique which we have found advantageous in the treatment of this type of fracture. It helps to prevent any untoward postoperative displacement, and minimizes, if it does not entirely obviate, the need for the various types of pins and screws that have been used to maintain the fragments in position.

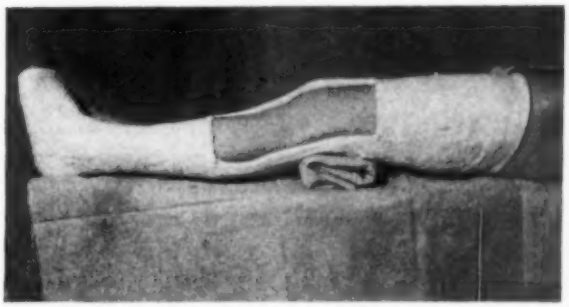


Fig. 1. Cast applied, with window removed when open operation is indicated.

In the fresh fracture, particularly if there is much swelling, after the effusion of blood has been removed by aspiration, the leg should be placed in a Thomas or Cramer splint and a pressure dressing applied. Repeated aspirations may be necessary, but as soon as the swelling has disappeared (four to eight days), a closed reduction is attempted under gas and oxygen anesthesia. At this time the Böhler[9] or Forrester's[10,11] redresseurs, or Caldwell's[5] "nutcrackers" are used in an attempt to procure the correction, especially in the spreading fractures. Great care must be exercised to avoid injury to soft parts, especially the common peroneal nerve. A well-fitting plaster cast is then applied, forcing the knee into the maximum varus position. The cast should be suitably padded over the outer side of the ankle, the outer side of the thigh, and the inner side of the knee, and should extend from the trochanter to the toes. The foot must be incorporated to insure against slipping of the cast and to maintain the position of the knee joint. This is often all that is required to obtain a satisfactory reduction, especially in fractures belonging to group 1.

When the plaster has set, further roentgenograms are taken. If satisfactory reduction has not been obtained, which is almost certain to be the case in depressed comminuted fractures (those of group 3), a large window is cut in the outer side of the

A B

FIG. 2. A, fracture of external condyle of right knee. Valgus position of limb. The patient was a woman 42 years of age. B, roentgenogram, showing reduction after operation. Fragment maintained in position by impaction only, with no bone peg or screw.

A B

FIG. 3. A, roentgenogram of same case shown in Figure 2. Maintenance of correction two years after operation. B, photograph taken two years after operation. Note prevention of deformity. Patient has full range of motion and no disability.

cast (Fig. 1), exposing the lateral aspect of the knee. After any reaction from the manipulation has subsided, the exposed portion of the knee is suitably prepared, and under gas and oxygen anesthesia the fracture site is approached through a longitudinal incision along the lateral aspect of the knee anterior to the lateral ligament. This allows exploration of the joint and the fractured surface of the tibia. The external semilunar cartilage can also be explored, but it has been my experience that removal of the meniscus is seldom indicated. The details of the operation depend upon the findings following exploration.

During the closed reduction of fractures of group 2 a single large fragment is occasionally pulled upwards into position by the collateral ligament, which is usually intact. In those cases which were unsuccessfully reduced by manipulation alone, Böhler[9] suggests the elevation of the depressed tuberosity by means of a strong metal pin introduced through a small puncture hole in the skin and levering the fragment into position. This procedure, although effective, has not proved in my experience so satisfactory as the reduction of the fragment under direct vision in an open operation. A bone peg can be used to maintain the reduction, but usually after the fragment is replaced, a slight impaction is all that is necessary for this purpose. Due to the fact that the knee is fixed in a plaster cast during the operation, there is no possibility of dislodging the fragments once they have been reduced.

With the depressed comminuted fractures (group 3), the greatest difficulties are encountered. The cartilaginous plate is broken down and cracked into multiple pieces, as an eggshell might be broken. Due to this comminution, very little if any correction is obtained by the original manipulation. In addition, there is usually such fragmentation that the use of screws or pins for fixation of fragments is not practical. The contour of the condyle should be re-established by elevating the crushed cartilage from below by a dull, flat, periosteal elevator or similar instrument, until the articular surface is even and raised to the proper level to overcome the depression. This is by no means so easy as it sounds, since to restore a smooth plateau requires meticulous care and patience.

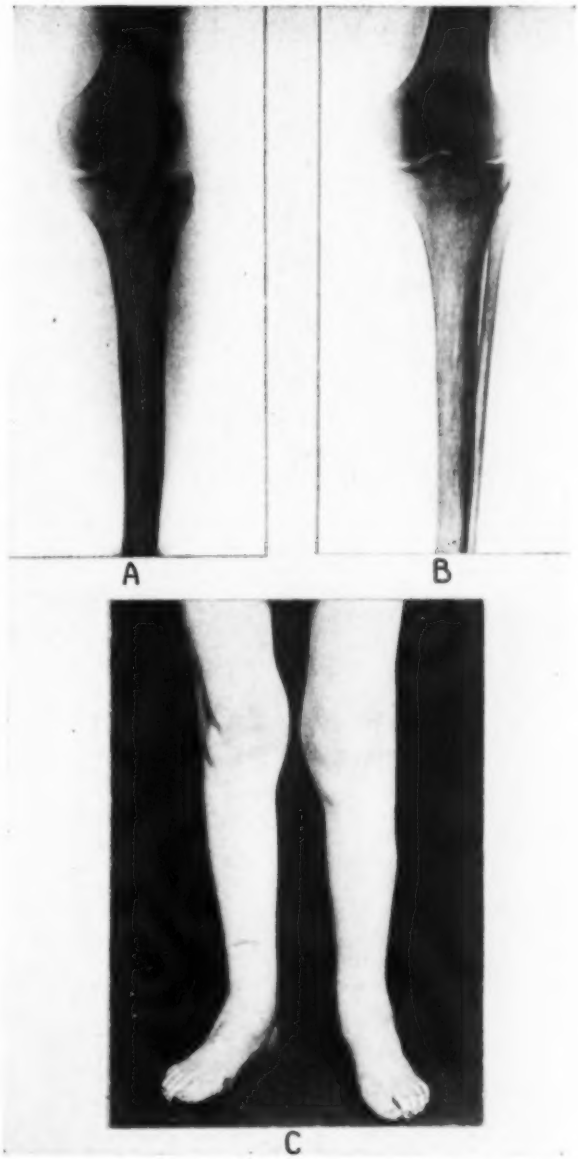
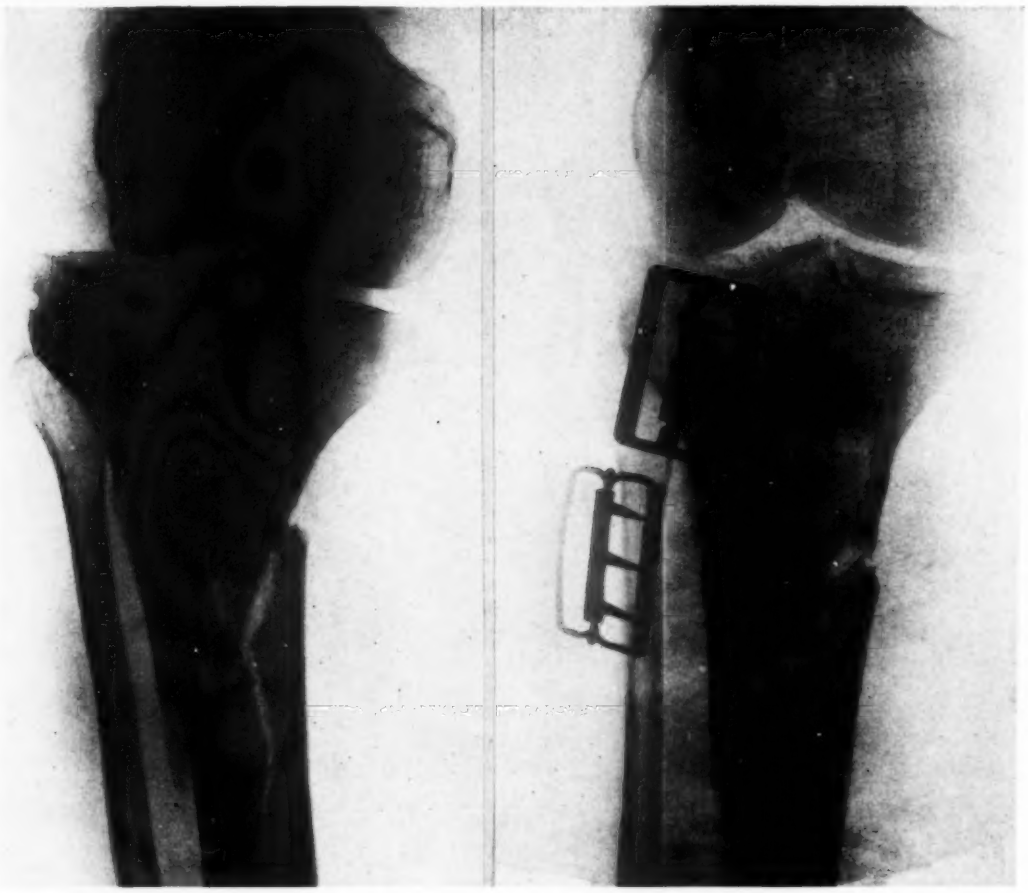


Fig. 4. A, fracture of external condyle, left knee, with outward displacement and compression. Before reduction. B, *x*-ray taken one year after reduction. Outward displacement corrected. Tibial articular surface even and level. The plateau was elevated and bone chips were used. C, photograph taken one year after reduction. There is no valgus deformity and the knee has active, painless motions from complete extension to well over 90 degrees flexion. This patient was 72 years old.

When the cartilage has been sufficiently moulded to overcome the condylar depression, the defect under the cartilage so produced is packed with small bone chips and cancellous bone obtained at a lower level of the tibia. When the condyle has been sufficiently repaired, the wound is closed and a pressure dressing applied. The advantages of having the leg maintained in the cast in varus position while the condyle is being reconstructed is obvious. The condyle of the femur remaining a fixed point, the tibial plateau is moulded up to it. As it is necessary to use soft cancellous bone and fine chips to support the plateau, it is good to know that the leg is already fixed in a cast. With this protection, no inadvertent manipulation of the leg can take place which might produce displacement of the fragments during the application of the plaster. Thus, one is assured of maintenance of the corrected position of the fragments until consolidation has been obtained.



A B

FIG. 5. A, severe fractures of both condyles of the tibia. B, reduction which was obtained by traction and lateral compression.

TREATMENT AFTER REDUCTION

As much depends upon the after treatment as upon the reduction, and adequate protection must be afforded. The cast is worn from eight to twelve weeks, depending upon the type of fracture and the degree of repair. At the end of this time a walking caliper or knee cage is worn until the end of the sixth month. During this interval, depending upon the repair as revealed in the roentgenograms, the cast may be bivalved, and physiotherapy, together with active and passive exercises,

may be instituted. Weight bearing without protection must be guarded until firm bony repair has been procured.

SUMMARY

Eliason and Ebeling,[12] Cotton and Berg,[2] Swett,[8] and Forrester[10,11] have strongly advocated non-operative treatment, but everyone will agree that a good anatomic restoration of the knee is of prime importance as long as this can be accomplished without undue trauma to the structures.

A closed reduction is always attempted in the first instance. If this should not prove effective, an open operation is carried out through a window in the cast. Since we have adopted this method of treatment for condylar fractures of the tibia, the results have been most gratifying. This approach allows the maximum of correction of the deformity and the maintenance of this correction without the use of metal pins and screws.

The subject matter in this article has dealt largely with fractures of the external condyle of the tibia, but similar principles can be applied to repair the internal condyle. Three cases of our series are presented to show the end results, one from group 2 (Figs. 2 and 3) and one from group 3 (Fig. 4). When the fracture involves both condyles, the use of the plaster cast by the method described is obviously not applicable and in these cases, correction is obtained by means of traction and lateral pressure (Fig. 5).

I feel confident that many of the writers who have expressed pessimistic opinions as to operative results will find this procedure helpful in dealing with those fractures of the condyles which seem to require more correction than can be obtained by closed reduction alone.

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FRACTURES OF BOTH BONES OF THE LEG

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THERE are on the market, at the present time, a large number of complicated instruments and devices designed to aid the surgeon in the care of fractures. Undoubtedly all have proved useful and valuable to certain ones of us in particular cases, though some of them have since been discarded for simpler methods. There also have been many methods described for the care of fractures of this type. Many surgeons seldom use internal fixation, and others almost routinely use it; some treat compound fractures by maintaining them as open wounds, while others prefer to close them as promptly as possible and convert the compound fracture into a closed fracture. This multiplicity of appliances and ideas as to methods of treatment is certainly evidence that no single method is entirely satisfactory in all cases and among all operators.

Corwin Hospital, of The Colorado Fuel & Iron Corporation, serves as a concentration point for diseases and injuries of Company employees and their dependents. The Corporation operates a large steel plant in Pueblo, Colorado, iron mines in Wyoming, and coal mines and lime quarries throughout Colorado. All fractures of consequence are splinted by the local physician and sent to us immediately. As a result of this, we see many fractures and each week we average more than one fracture of both bones of the leg.

It is not our purpose in this paper to present any radical departure from accepted methods of treatment of fractures of both bones; but we will endeavor briefly to point out some of the considerations we have found to be important and valuable in the treatment of this condition, hoping that it may prove of some value to others.

In the treatment of simple fractures involving both the tibia and fibula, or in less severely comminuted fractures, we are inclined to a position of considerable conservatism. In many of these cases, particularly where they have been handled carefully prior to their presentation at the hospital, the position will be found to be satisfactory. In such cases we apply a snug-fitting, long-leg cast, extending well up on the thigh, at the earliest possible time, without unnecessary handling or manipulation, and without unnecessary attempts to improve slightly the position, lest a simple fracture be converted into a difficult one. Frequently, when there is a slight angulation at the fracture site—and particularly with an oblique fracture where there is possibility of displacement—it may not be corrected until three weeks later, after healing has started and displacement is less likely. At this time, the cast is wedged to bring the fracture into proper alignment.

For those cases where position cannot be considered satisfactory, we feel that the simplest type of procedure which will accomplish the desired result is preferable. Therefore, under general anesthesia, we have found that the majority of these cases can be manipulated into satisfactory position and secured in plaster immediately upon admission, providing the patient's general condition does not preclude this procedure. If the patient is in shock, that condition should be treated immediately, and the fracture cared for thereafter as soon as possible. We use local anesthesia in some of these cases, and have in the past used spinal anesthesia for many of them, though we feel that a general anes-

thetic is preferable. We have found that the earlier such restoration of anatomical position and immobilization can be accomplished, the quicker and better will be the result which will follow. We have found open reduction with internal fixation unnecessary in most of these cases, and do not favor the use of traction in such cases as can be handled without. We have almost completely abandoned the use of the Böhler walking iron, as we have failed to see much benefit from it. We have found that in the majority of cases where there is an oblique or spiral fracture of the tibia, with fracture of the fibula, they can be satisfactorily reduced and maintained in plaster. We do feel, however, that with spiral fracture of the tibia and with the fibula fractured high, time, suffering, and disability are reduced by open operation. We feel that the Carroll-Girard screw will be very helpful in these cases, but our experience does not, as yet, permit a definite opinion as to its value in our hands. All cases are followed carefully by *x*-ray before and after reduction, and at intervals during the progress of healing.

In the relatively small percentage of cases where it is not possible to obtain satisfactory reduction or maintain position by these conservative procedures, and in cases which are more severely comminuted, we do not hesitate to proceed immediately with reduction by other means. Traction is frequently used, in which case we prefer to employ a small Steinman pin in the os calcis. We only rarely use a Kirschner wire or ice-tong calipers. We use a Hawley suspension splint, or Brauns frame, and follow it with a cast, incorporating the pin in the cast. In some cases we employ internal fixation. Here we prefer to use an autogenous bone graft, or merely heavy chromic sutures. We rarely employ plates or other foreign substance which may subsequently have to be removed, necessitating a second operation and further time loss.

In cases of this type, where traction is necessary, we occasionally use the automatic splint designed by Dr. Roger Anderson, of Seattle. This is an excellent tool for reduction and maintenance of such cases and since the leg can be incorporated in plaster with the pins in place, it serves a most useful purpose. We feel, however, with the discussion of traction in these cases, that we should warn particularly against the danger of over-traction. Non-union occurs more frequently in the tibia than in any other of the common fractures, and most frequently at the junction of the middle and lower thirds. We feel that over-traction is a frequent causative factor in this non-union.

Fractures of the tibia and fibula are more frequently compounded than any other major fracture, probably because of the close proximity of these bones to the surface and because of their inherent strength and the great force required to fracture them.

Our first consideration in a severe fracture with extensive soft tissue injury, is regarding the viability of the limb as a whole. We are extremely conservative at this point and where there seems to be any reasonable chance to save the limb we endeavor to do so, though later it may be an imperfectly functioning leg.

We feel that every compound fracture should be converted to a closed fracture by immediate surgery. It is our practice that every such case, seen within approximately twenty-four hours of the time of injury, is taken immediately to the operating room, providing the patient's general condition will permit, and the wound closed.

In our procedure for closing such a wound, we first cover the wound itself with sterile gauze to prevent further contamination while the surrounding skin areas are being prepared. We shave the area and wash it thoroughly with ether to remove all fat soluble material. We then wash the entire area thoroughly with soap and water, and follow this with 3½ per cent iodine. With the surrounding skin areas prepared to prevent further contamination of the wound, we proceed to the wound itself. In this we would like to

emphasize the importance of mechanical sterilization. Any gross contaminating substances are removed from the wound and it is irrigated thoroughly with large quantities of sterile saline solution, care being taken to penetrate all the recesses of the wound. All devitalized tissue must be removed by sharp dissection, with the utmost care being taken lest the scalpel graft potential infection to clean tissue. If the bones have been ground into dirt, or otherwise grossly contaminated, the ends of the bone are trimmed. Pieces of entirely detached bone are removed. Adherent fragments are placed in a position advantageous for healing. We carry out the entire débridement, as we do with our other bone surgery, with a no-finger contact technique. It was formerly our procedure, after the wound had been carefully cleaned, to apply iodine in the open wound. We feel that, while this procedure perhaps has certain bacteriocidal action, its beneficial effect is neutralized by the destruction of delicate tissues within the wound, thus forming a coating of necrotic tissue through our entire wound and destroying the effect of our careful excision of all necrotic tissue. This procedure has, therefore, been abandoned, and with good results. In such cases we pay very particular attention to hemostasis. We feel that an absolutely dry wound should be obtained before it is closed. Either devitalized tissue left in a wound, or a hematoma formed by bleeding into a wound, serve as an excellent media for the growth of bacteria, and, protected from the bacteriolytic activities of the blood elements and tissue elements as they exist in living tissue, it furnishes an ideal opportunity for the growth of bacteria and the development of a fulminating infection which might necessitate a later opening of the wound or even endanger the patient's life. This method has, of course, been criticized because of this possibility, though we feel that where the proper care has been used in the preparation and closure of the wound it is done with perfect safety. In fact, we feel that by its complete closure without drainage the principal avenue of serious infection is closed, that further treatment will be greatly simplified, the healing period will be shortened, and the possibilities of a good result improved.

If any internal fixation is going to be necessary, it is done at the time the wound is originally cleaned and sutured, but if at all possible this is done without the use of non-absorbable foreign material. All soft tissue structures, nerves, tendons, and muscles are accurately repaired, the wound is never pulled together under tension. Where there has been considerable loss of tissue and skin, incisions are made at some distance to allow the skin to be closed without tension. The skin edges are never undermined. The wound having once been closed, the fracture can then be treated as a closed fracture.

CONCLUSIONS

1. Providing the patient's condition will permit it, all fractures of both bones of the leg should be reduced and immobilized as soon after injury as possible.

2. Where traction is used, particular attention should be given to avoidance of over-traction. We feel that separation of the bone fragments is a very common cause of non-union.

3. Compound fractures seen within the first twenty-four hours should undergo thorough mechanical sterilization, complete hemostasis should be secured, and the wounds closed to facilitate further handling of the fracture and minimize the danger of infection.

FRACTURES OF THE ANKLE

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FRACTURES of the ankle may be classed as important surgical conditions because they are of frequent occurrence, both in ordinary civil life and in industry: also, they involve an important weight-bearing joint and frequently result in a high grade of disability.

Since the writings of Percival Pott (1713–1781) and Dupuytren (1777–1835) many important contributions dealing with fractures of the ankle have appeared in the literature, and the whole subject has been so thoroughly elucidated that it seems impossible to add to the knowledge already available to those who wish to acquaint themselves with it. This contribution, which is based on a study of 164 cases of fracture of the ankle joint, can serve then bnt four purposes: (1) again to call attention to the mechanism of production of ankle joint fractures; (2) to suggest a working classification for those fractures; (3) to catalogue important diagnostic points; (4) to outline a plan of treatment, based upon the modern conception of the problems which these fractures present and modern methods of meeting these problems.

Fractures of the ankle joint include two distinct groups: In the first group, we have fractures of the leg bones, the lower end of the tibia and fibula. The second group comprises fractures of the astragalus. This discussion is limited to the first group—fractures of the lower end of the tibia and ffbula.

In considering the mechanism of production of fractures of the ankle, there are certain anatomical features in the architecture of the ankle joint which must be borne in mind, as they have a very important bearing on the behavior of the bones of the ankle when fractured. The ankle mortise is formed by the lower end of the tibia and fibula which are strongly bound together by ligaments. The action permitted by this mortise allows of an essentially hinge-like motion at the ankle joint, though not purely so, as the fibula moves to some extent on the tibia. The astragalus is held firmly in the ankle mortise by the internal and external lateral ligaments which pass from the tibia and fibula to the tarsus and are strong and tough, permitting little lateral motion. From the external lateral ligament, a strong band passes to the posterior surface of the astragalus, binding the astragalus strongly to the fibula (Fig. 1). There is no counterpart of this band on the mesial or inner side of the joint; consequently, in all injuries in which the tibio-fibular continuity is lost, the astragalus remains attached to the fibula and is displaced with it. This fact is the key to the problem of ankle fractures. It was the basis of the teaching of Pott and other writers that dislocation of the ankle was practically always accompanied by fracture of one or both bones of the leg, and caused Dupuytren to recognize fracture of the fibula as the pivotal injury in fractures of the ankle. With this brief anatomical discussion, we will pass on to a consideration of the mechanism of production of ankle joint fractures.

Direct violence plays a very unimportant role in fractures of the ankle (1 per cent according to Ashhurst). Indirect violence is responsible for most of the fractures of the lower end of the leg bones, acting through the astragalus in such a way as to produce a breaking strain. The forms of indirect violence are: (1) external rotation; (2) abduction or eversion; (3) adduction or inversion; (4) upward compression thrust against the lower tibial weight-bearing surface.

1. External rotation. In this movement the foot is rotated outward around the vertical axis of the leg, and the force is transmitted to the fibula as a torsion strain which breaks the fibula in a spiral or oblique direction. The tibio-fibular ligaments usually remain intact, and there is little diastasis of these bones. If the violence continues, the next injury produced is a rupture of the internal lateral ligament or tearing off of the internal malleolus.

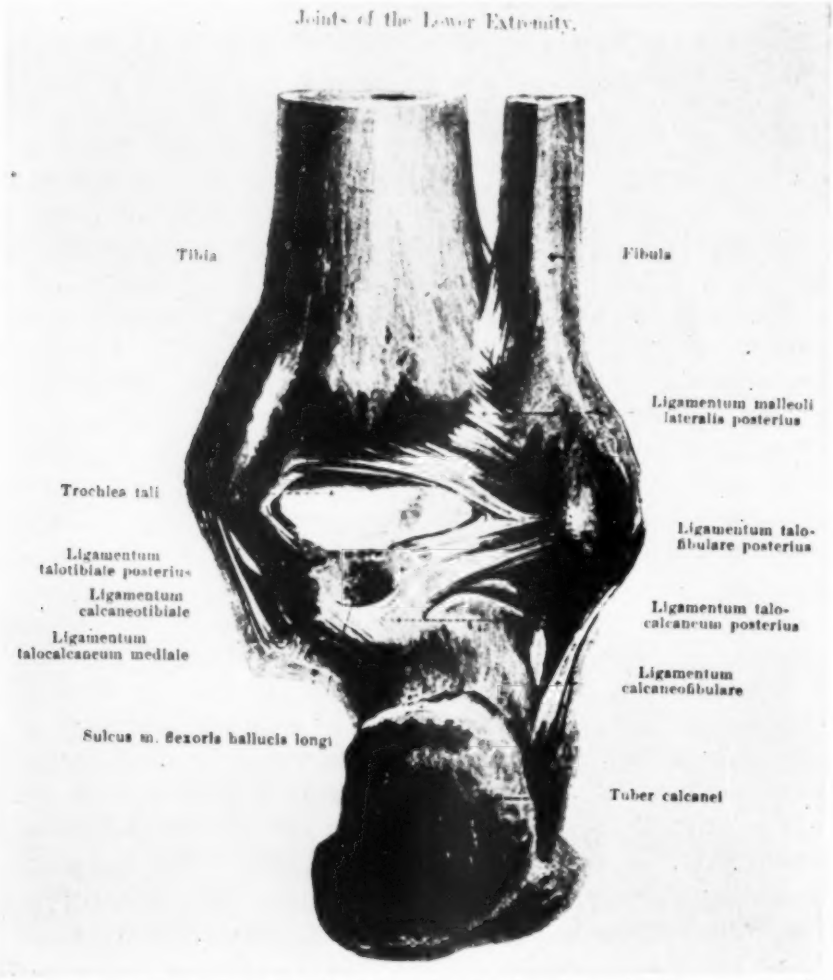

Fig. 1. Lateral ligaments of ankle joint, showing band running from external lateral ligament to astragalus.

2. Abduction (eversion). When an abducting force is applied at the ankle, the astragalus tends to rotate outward in the mortise and exerts a bending strain against the fibula and a strong tension on the internal lateral ligament. It is probable that the most frequent sequence of events is rupture of the internal lateral ligament or tearing off of the internal malleolus and then fracture of the fibula. The line of fracture through the fibula may be below the tibio-fibular ligament, when it is usually transverse, or above through the slender surgical neck, when the fracture is usually oblique. Diastasis of the tibio-fibular joint does not occur when the fracture of the fibula is low down; when high up, it is usual.

3. Adduction (inversion). With this form of violence, the astragalus rotates inward in the ankle mortise; the primary lesion is a tearing off of the external malleolus, a fibular fracture. The continued violent thrust of the rotated astragalus against the internal malleolus causes it to fracture secondarily.

4. Upward compressive thrust against the lower tibial articular surface. Such fractures most commonly occur when an individual falls from a height and lands on his feet with sufficient force to exert a strong upward impact against the lower tibial weight-bearing surface. Such force results in the separation of a triangular fragment from the posterior surface of the tibia, the line of fracture extending down into the ankle joint. Such a fracture is called a posterior marginal fracture. The fragment displaces with the astragalus and fibula. This fracture may occur alone but is usually associated with fracture of the internal and external malleoli. There is some lateral displacement of the ankle in this fracture, but the chief displacement is a backward one of the astragalus. Occasionally the same type of fracture, involving the anterior margin of the lower articular surface of the tibia, occurs when it is known as an anterior marginal fracture. The term "trimalleolar fracture" has been suggested by M. H. Henderson to describe fractures of the malleoli complicated by the anterior or posterior marginal fractures.*

Fig. 2. Isolated fracture of fibula.

Fig. 3. Isolated fracture of internal malleolus.

The relative incidence of these four forms of indirect violence has been a matter of investigation. Probably the most recent and authoritative compilation since the introduction of radiography is that of Ashhurst[1] which includes a group of 300 cases. Ashhurst considered external rotation the cause of fracture in 61 per cent of the cases, abduction in 21 per cent, adduction in 13 per cent, and posterior marginal fractures in 19 per cent of the cases. Platt[2] in 116 cases found about the same relative incidences, as did also Kellogg Speed.[3] In this group of 164 cases

* Destot used this term over thirty years ago.—Editor's Note.

about the same percentages as given by Ashhurst were found. So much depends upon personal opinion in interpreting radiographs that such statistics can be only approximate.

Fig. 4. Bi-malleolar fracture without displacement of the astragalus.

Fig. 5. Bi-malleolar fracture with displacement of the astragalus.

CLASSIFICATION

For a clear understanding of fractures as complicated as those encountered about the ankle, it is desirable that some classification be generally adopted. Various groupings of the fractures of the ankle have been suggested. There is the historical classification in which the name of some great surgeon has been attached to a particular fracture, such as Pott's fracture, Dupuytren's fracture. A classification based on the mechanism of production has been advocated, as abduction fracture, adduction fracture, etc. Finally, we have a classification based on an anatomical or physiological foundation, as bi-malleolar fracture, isolated fracture of the fibula, etc. It is desirable for clarity in surgical teaching that as simple and descriptive a classification as possible be generally adopted. Platt, whose paper with that of Ashhurst constitutes the most authoritative recent contribution to this subject, has suggested a classification based on the more elaborate one of Tonton which seems to fulfill the requirements of simplicity and descriptiveness. The classification here given is essentially that suggested by Platt. It is as follows:

A. Fractures of the malleoli
   1. Isolated (a) fibula (Fig. 2)
      (b) internal malleolus (Fig. 3)
   2. Combined (a) low bi-malleolar without displacement of the astragalus (Fig. 4)
      (b) bi-malleolar with displacement of the astragalus (Potts-Dupuytren fractures) (Fig. 5)

B. Fractures of the weight-bearing surface of the tibia:

1. Isolated (a) posterior marginal fracture (Fig. 6)
   (b) anterior marginal fracture (Fig. 7)
2. Combined (a) anterior or posterior marginal fracture associated with fractures of the malleoli (Fig. 8)

Such a classification is simple enough for the purpose of keeping records and at the same time is sufficiently descriptive of the condition found.

In this series of 164 cases, isolated fracture of the fibula occurred in 31, or 18.5 per cent; isolated fracture of the internal malleolus, fourteen times, or 8 per cent; combined bi-malleolar fracture without displacement of the astragalus occurred twenty-six times, or 15.8 per cent; bi-malleolar fracture with displacement of the astragalus (Potts-Dupuytren) occurred fifty-five times, or 33.5 per cent. Fractures of the lower articular surface of the tibia occurred as follows: isolated posterior marginal fractures, eight times, or 4.8 per cent; isolated anterior marginal fractures, four times, or 2.4 per cent. Combined anterior and posterior marginal fractures, associated with fracture of the malleoli occurred twenty-six times, or 15.8 per cent. The most interesting feature of these figures is the frequency with which fracture of the lower articular surface of the tibia occurred. Adding the per cent of isolated anterior and posterior marginal fractures (totalling 7.2 per cent) to the 15.8 per cent of cases in which fracture of the weight-bearing surface occurred with fracture of the malleoli, we find that fracture of the lower articular surface of the tibia occurred in 23 per cent of 164 cases. Ashhurst in 300 cases reported 19 per cent of posterior marginal fractures but did not segregate these into isolated and combined groups. It is evident from these figures that fracture of the lower articular surface of the tibia which adds greatly to the seriousness of fracture of the ankle joint, occurs in slightly more than one-fifth of the cases. This fact is important.

Fig. 6. Posterior marginal fracture.

DIAGNOSIS

It seems scarcely necessary in a condition so familiar to all physicians as fractures of the ankle to discuss symptomatology. It may be worthwhile, however, briefly to mention outstanding diagnostic points.

The history of an injury in which the type of violence was forcible movement of the foot is always an important lead toward diagnosis of fracture of the ankle. The injury is a severe one, as a rule; and it is practically impossible for the individual who has suffered an ankle fracture to walk.

The foot is held in plantar flexion, and there is eversion or outward displacement of the foot. (Fig. 9.) The latter may be slight or marked, depending upon the degree of displacement of the astragalus. The internal malleolus is prominent.

Increased lateral mobility is probably the best test of ankle fracture, except in isolated fracture of the internal malleolus lateral mobility is easily demonstrated. During such manipulation, crepitus can be felt if present.

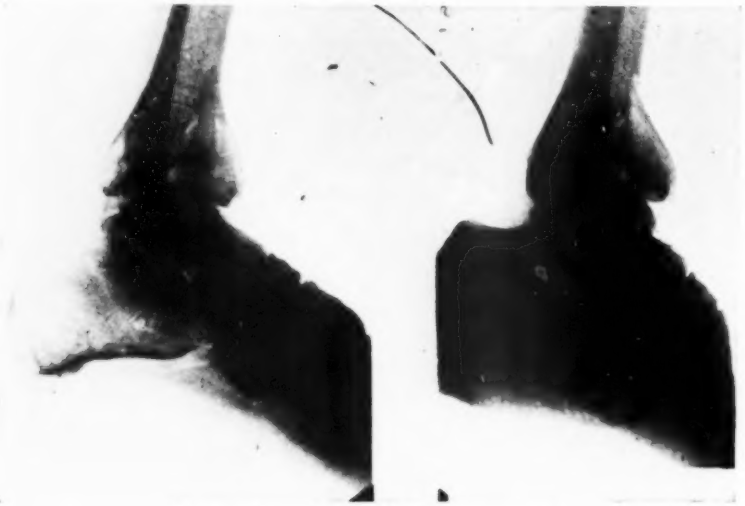

Fig. 7. Anterior marginal fracture.

Fig. 8. Posterior marginal fracture combined with fracture of the malleoli.

or fibula. This is best tested for by grasping the ankle with one hand, while the other hand is placed beneath the sole of the foot with the thumb and fingers grasping the sides. The foot is then gently moved inward and outward, and any increased

In posterior marginal fractures, two signs, pointed out by Cotton, are important: (1) prominence of the anterior margin of the tibia, which, however, is less as a rule than in complete dislocation of the ankle; (2) marked instability of the ankle

and consequent tendency for the deformity to recur after reduction.

Finally, and perhaps most important in that it gives direct visual evidence, is the radiographic examination. If we bear in mind that many fractures of the ankle occur without gross displacement, the value of a skiagram in diagnosis is manifest. The skiagram should be taken in two planes, anterior-posterior and lateral, to insure a complete investigation of conditions. Frequently an external rotation fracture of the fibula does not show or is barely discernible in an anterior view, but is quite evident in a lateral view. (Fig. 10.)

Accuracy in diagnosis of fractures of the ankle is of paramount importance, as it is in all fractures involving a joint, because of the grave disability which results when such fractures are undiagnosed and receive inadequate treatment or no treatment at all. Especially is it necessary to exercise care in diagnosing the condition of the ankle when the lesser degrees of displacement are encountered. It is this type of ankle fracture which is most likely to be overlooked, to the detriment of the patient and the reputation of the medical attendant. The more serious forms with evident displacement are, as a rule, recognized at once and given adequate treatment.

A special word of warning should be said with regard to posterior marginal fractures. Apparently in a surprising number of cases, while the bi-malleolar fracture is recognized and the lateral deformity corrected, the posterior marginal fracture is overlooked or the importance of completely reducing the posterior displacement of the foot and accurately restoring the contour of the lower articular surface of the tibia is not appreciated. If this is not done, after the fracture heals, limitation of ankle flexion and extension persists, a painful ankle results which very definitely interferes with function, and a permanent disability is established. (Fig. 11.)

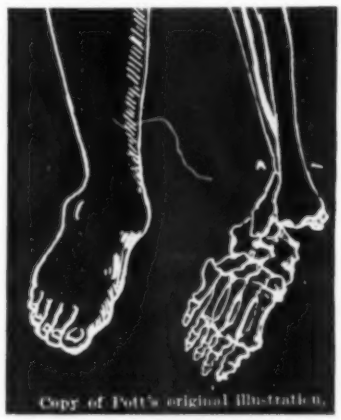

Fig. 9. Percival Pott's original drawing of fracture of the ankle.

Fig. 10. Fracture of fibula. Apparent in lateral view; not apparent in anteroposterior view.

Anterior marginal fracture, while not so common as posterior marginal fracture, is a very serious complication in fracture of the ankle. This fracture is not frequently accompanied by a forward displacement of the astragalus, but unless it is accurately reduced, serious limitation of plantar and dorsal flexion of the ankle joint results.

Fig. 11. Unreduced posterior marginal fracture healed in malposition. High grade disability.

TREATMENT

It is the routine in our clinic that all ankle fractures be reduced at the earliest possible moment and fixed in a plaster cast.

Reduction is made under full anesthesia or local anesthesia. The knee should be flexed to a right angle. The ankle is grasped with one hand, pressure being made outward in the region of the internal malleolus. The foot is grasped with the other hand well back toward the heel, the thumb resting just below the external malleolus and the fingers grasping the inner side of the heel. (Fig. 12.) With the hands in this position, the foot is inverted and pushed sharply inward. Particular care must be taken to see that the heel is inverted and not merely the movable anterior part of the foot, since it is through the posterior part of the foot that the fragments are controlled. Only a moderate degree of inversion is necessary, but we have never seen any harm come from too much inversion. When backward or forward displacement of the foot is present, this must be corrected by appropriate manipulation. In the occasional case in which we have an inversion displacement instead of an outward displacement, reduction is the opposite from that described here, and the foot is put up in its normal position, over-correction should be avoided because of the danger of later flat foot. The essential feature of the reduction is a restoration of the ankle mortise. Failure

Fig. 12. Method of reducing fracture of the ankle.

to achieve this results in a faulty weight-bearing surface at the ankle joint, and a painful and impaired extremity which can be improved only by later operative interference. (Fig. 13.) Check skiagram should be taken after reduction, and if there is any doubt as to the maintenance of the reduction, other checks should be made at intervals.

Fig. 13. Unreduced bi-malleolar fracture healed in malposition.

After reduction, with the foot inverted and as close to a right angle as possible, a cast is applied over a sheet wadding bandage or directly to the skin, and the cast immediately bi-valved. Bi-valving the cast takes care of subsequent swelling, allows of easy access to the entire limb for inspection, and at the same time holds the fractured bones firmly in place. (Fig. 14.) Many experienced surgeons prefer to fix the leg in a pillow splint or fracture box for the first three days to a week after reduction before applying plaster. It is generally conceded, however, that the fracture can best be controlled by the immediate application of plaster, and that swelling is less and disappears more rapidly with such firm fixation. All agree that immediate reduction is best.

Early weight bearing has come to be considered highly desirable in fractures of the ankle joint, provided firm fixation can be maintained. There are two methods in use for fixing fractures of the ankle joint and at the same time permitting weight bearing: (1) providing the cast with a weight bearing heel piece; (2) incorporating a walking stirrup which projects below the cast and protects the foot from contact with the ground.

Fig. 14. Cast applied and bivalved.

The first of these methods is quite simple and the one most suited to general use. The method consists of applying a cast in the manner described and after it is applied building an elevation on the heel; this heel elevation takes the weight and allows the fore part of the foot to clear the ground. If the heel elevation is made of several layers of sponge rubber it is most comfortable. The rubber heel is attached to the cast by a few turns of plaster bandage: this softens under the impact of weight bearing and allows the individual to walk quite comfortably with crutches or even without them. (Fig. 15.)

Fig. 15. Cast with rubber heel for walking.

The second method uses a U-shaped stirrup of strap iron which projects below the foot. The arms of the U are incorporated in the sides of the cast. Weight is borne upon the projecting loop of the stirrup, thus short-circuiting the weight about the ankle joint.

The after-treatment, if weight bearing is not permitted, consists in removing the anterior half of the cast at the end of the second week and starting light massage and toe movements, the posterior shell remaining in place. In four weeks the foot is removed from the plaster shell and gentle motion allowed. At the end of six to eight weeks, depending upon the severity of the fracture, the cast is discarded and a shoe used into which a hard felt arch is fitted. This supports the arch and maintains inversion of the foot. At times, it is desirable to elevate the inner edge of the shoe three-sixteenths of an inch for a month, or until full strength has returned to the supporting muscles. If a weight

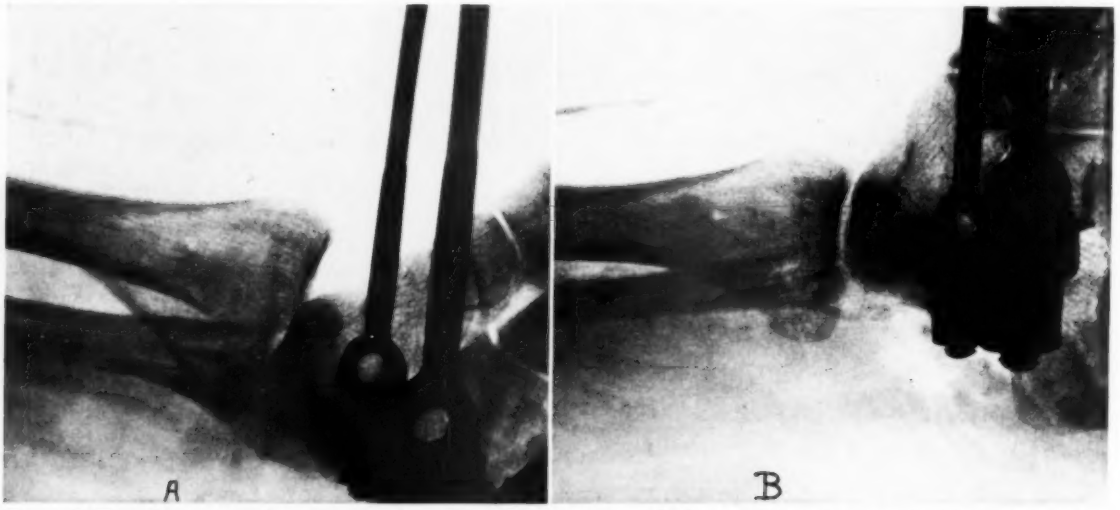

Fig. 16. Traction correction of posterior marginal fracture. A, before, and B, after application of traction.

bearing cast is used, it remains on from six to eight weeks and then a balanced shoe is applied.

There are special features in the treatment of anterior and posterior marginal fractures which should be emphasized, since these fractures present some problems which require special care in management.

In posterior marginal fractures, the reduction is important. Under general or local anesthesia, the knee should be flexed to relax the tendo-Achilles and the posterior part of the foot strongly adducted and inverted with the ankle in moderate equinus to bring the foot into alignment with the leg. Since the astragalus and the marginal fragment are attached to the fibula and, in fracture of the ankle, displaced with it, it seems logical that the primary step in reduction should be the correction of the fibular displacement. When sufficient adduction and inversion have been secured to correct the lateral displacement, the foot should be pulled forward to correct the posterior displacement and brought into complete dorsal flexion. Dorsal flexion should make the posterior ligament, which is seldom torn, tense, and so tend to mold the displaced tibial fragment back into place and hold it there. A plaster cast is immediately applied and for two weeks is allowed to extend above the knee, which is held in moderate flexion. Any tension on the tendo-Achilles should, we believe, be avoided for this length of time, as it may cause a recurrence of the posterior dislocation and displacement of the marginal fragment. After two weeks the cast is cut down below the knee, and the usual after-treatment of fractures of the ankle followed. Weight bearing is not permitted under eight weeks. The instability of the ankle in posterior marginal fractures should be constantly borne in mind and a check-up roentgenogram made immediately after the application of the cast. The position should be checked at least once or twice more during the first ten days or two weeks following reduction.

If, after the reduction of a posterior marginal fracture, instability of the ankle persists, as happens from time to time, and the deformity recurs even after the application of a plaster cast, the following method to hold the displaced marginal fracture in place and prevent persistent posterior dislocation of the foot has been used in our clinic with satisfactory results. The leg is encased in a plaster cast from above the knee to the ends of the toes, the cast being heavily padded about the lower end of the tibia. The front of the cast is then removed from the ends of the toes to the level of the lower end of the tibia, leaving only a posterior shell. A Kirshner wire is then passed through the astragalus and, using an overhead pulley, direct traction is made upward, or in reality forward, on the foot. Counter-traction is supplied by the pressure of the cast against the lower end of the tibia. (Fig. 16.) Such traction is allowed to remain on for three weeks. In four cases in which this method has been used, it was found quite efficient and accomplished and retained reduction.

In the treatment of anterior marginal fracture, accurate reposition of the tibial marginal fragment must be secured. Frequently this can be accomplished only by open reduction and internal fixation of the fragment.

Fractures of both the anterior and posterior margin of the tibial weight bearing surface so frequently are difficult to reduce and maintain in position and so often result in an impaired joint that their management constitutes a most difficult problem in fracture treatment. It may be truly said that the management of such fractures requires an experience and an armamentarium which few general practitioners possess and that probably such fractures are best referred for special treatment.

Any discussion of compound fractures of the ankle and of the open reduction of ankle fractures has been purposely omitted. These conditions have aspects that entitle them to be considered as special varieties

of ankle fractures and to introduce them here could serve no purpose but that of complicating this presentation. It is sufficient to say that if closed manipulation fails to secure reduction, open reduction should be resorted to. Open reduction of an ankle fracture is not a simple problem and should be carried out by those qualified properly to perform such an important and at times hazardous procedure.

Old fractures of the ankle with deformity and persistent disability require treatment for the relief of pain and to restore function so far as possible. Improvement in both respects can as a rule be secured by proper palliative or operative measures. Each case, however, is largely an individual problem, requiring such reconstruction as is necessary to eliminate the pathology present, and a discussion of the problem involved would prove too exhaustive for consideration in this paper. Suffice to say that many of those with extensive experience have come to feel that arthrodesis of the ankle, a procedure which gives a good weight bearing, pain-free extremity is usually to be preferred to a remodelling operation. These latter while they frequently improve the position of the foot and appearance of the joint, too often fail to provide a useful range of ankle motion, with the result that function is definitely impaired, the ankle remains painful, and weight bearing for any prolonged period of time is impossible. Certainly remodelling operations are rarely successful if the displacement has persisted for a number of months, because of periarticular changes and more or less destruction of the articular cartilages of the joint.

CONCLUSION

Fractures of the ankle constitute a serious injury, in that interference with the function of an important weight bearing joint so often results. Accurate diagnosis, exact reduction, efficient fixation, and careful after-treatment are necessary if the patient is to receive the best result he is entitled to. It is of little importance that gifted or fortunately placed surgeons can point with just pride to a large percentage of successful results in ankle fractures. It is of importance, however, that the standard of treatment generally be of such excellence as to insure a high percentage of good results with strong, satisfactory weight bearing extremities. A century ago the dictum of Dupuytren may have had some justification—"Under the most favorable condition they (fractures of the ankle) almost always leave deformity and lameness, which renders progress difficult or painful." Today with the *x*-ray and modern facilities for treatment such results should be the exception and not the rule.

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FRACTURES OF THE BONES OF THE FEET

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THE common fractures of the bones of the feet will be dealt with in this article, and little or no attempt will be made to speak of the unusual or rare fractures seldom seen. Owing to the fact that the foot is subject not only to the trauma of strain, but is also peculiarly liable to injury from crushing and the impact of falling objects, there result a great variety of injuries that cannot be classified nor dealt with here.

Certain generalities should be carried in mind by the reader to avoid necessity of repetition. For instance, those fractures with sufficient displacement to cause tissue tension, threatening skin slough and subsequent sepsis require very prompt attention. The fractures which are compounded need equally speedy treatment—in fact, those not handled within four hours show a rapid rise in the incidence of sepsis.

In those requiring open operative treatment, skin incisions should be made with careful thought to avoiding the more important weight bearing and pressure points of the foot. Painful scars beneath the great toe joint or under the calcis are to be avoided if possible.

Early motion is to be sought, but let us remember to provide adequate and prolonged protection to certain types of fractures with prevention of such sequelae as acute foot strain, metatarsalgia, valgus deformity and its accompanying spastic flat foot.

SESAMOIDS

Fractures of these small cartilaginous masses are usually not important. They may be acquired from a weight bearing twist of the foot, a fall landing on the ball of the foot or from a crushing weight as a rock dropping on the great toe metatarsophalangeal joint. Diagnosis is made by *x*-ray. The sesamoid under the great toe is probably the commonest and most liable to cause trouble. It may be bipartite or double type ossification centre—two together, resembling a fracture.

Treatment: Conservative or operative.

Anterior arch support taking the weight off the tender area may be tried for a reasonable length of time—a month or two—but if this fails, remove sesamoid placing the incision as advantageously as possible to avoid painful scar. This painful scar business must be kept in mind in all operative procedures on the feet, just as carefully as we figure out incisions on the fingers and hands to avoid interference with function and comfort.

Bipartite sesamoids are often mistaken for chip fractures and might be important in legal cases.

Repair as shown by *x*-ray is usually fibrous, seldom true bone union.

PHALANGES

Fractures of phalanges are often unnoticed. They may be caused by a rotary twist or by "stubbing the toes," but most often by dropping heavy objects on the toes. True bone repair often does not occur in the distal phalanges. A fibrous union takes place with a fairly uniform good result, usually minus pain. A very few fractures of the phalanges remain painful, requiring amputation of part or the whole toe.

Treatment: Plantar splint or plaster sole extending out beyond the ends of the toes. Traction is hard to maintain, and seldom necessary. A plaster mould or gutter may be applied over sheet wadding, giving lateral and plantar support to straighten

a toe in bad position. This is incorporated into the plaster sole or boot. About four weeks minimum, or better, six weeks, had

Fig. 1. Incision for removal of sesamoid beneath great toe.

best elapse before direct weight bearing is allowed.

Dislocation of all toes, as from stepping up on a curb and slipping back, the toes taking all the weight bearing, does occur! Manipulation and plaster with toes in semiflexion in well padded cast cares for a condition that is crippling unless well handled.

METATARSAL FRACTURES

The most important injury is that to the fifth metatarsal near the proximal end. Sometimes these do not unite and are tender on walking, since they take a large share of the weight bearing on the outside of the foot.

Causes: Sharp inversion of the foot commonly called "turning the ankle." Weight is thrown suddenly on the outer side of the foot: tendon attachments and body weight cause fracture by cross leverage over the fulcrum of the firmly attached base. Hence the break is always and constantly just in front of this base. Displacement is mostly slight, if present at all. This injury is easy to miss, so *x*-ray this type of accident as you do all other suspected damage to bones elsewhere in the body.

Treatment: Plantar splint or plaster sole for six weeks minimum, without weight bearing. It is well to warn the patient that a bone graft may be necessary in a fracture of the proximal end of the fifth metatarsal bone.

Fractures of the metatarsals, other than the fifth already mentioned, usually respond to manipulation and manual traction. A plantar splint or plaster sole worn for four to six weeks cares for the majority.

Certain complicated fractures of these bones, multiple in nature, do occur, as in a fall in which one lands on the ball of the foot. Two, three or four bones may be partially avulsed from their beds—usually at the proximal ends. Manipulation may restore position, but often an open operation with pinning by wire or nails may be required. Following operation, prolonged fixation in plaster should be maintained for six weeks or more. Removal of nails or wires may be required after patient resumes walking on foot. Motions and pressure tend to loosen metallic substances in the foot more than elsewhere in the body.

It is seldom necessary to shorten the metatarsal to replace its end back in place. We have in mind, in this relation, only those injuries with a tearing out of the bone ends from their normal relations.

The second metatarsal, and the longest of its name, fits at its proximal end into a recess formed by the three cuneiforms. Fractures at its proximal end may, and often do, involve one or more cuneiform bones. This may be a clean crack through number one, two or three cuneiform, but usually it results in a crushing and mass damage in this articulating area. Conservative treatment is usually satisfactory here. A plaster boot is required for only six weeks, but disability is of many months' duration.

It is extremely important in metatarsal fractures that in the lateral *x*-ray film there be no anterior or posterior angulation of the bone. This is far more important clinically than a deviation to right or left, as seen by antero-posterior view. A hard knuckle of bone pressing down against

tendon or other soft tissue may necessitate an osteotomy at a later date. Or the reverse, an anterior projection may cause either dysfunction of foot statics or a pressure prominence irritated constantly by the shoe.

The occasional metatarsal fracture may progress better if a small plate and screws are used, similar to those used in certain metacarpal fractures by Otto Hermann.

Preservation of a proper anterior or "transverse" arch is important in treatment of severe metatarsal injury. This should be constantly kept in mind.

CUNEIFORM FRACTURES

These are relatively rare as isolated fractures. Cracks through these cuneiforms should be protected for adequate time by immobilization in plaster or by padded plantar splint without weight bearing.

INJURY TO NAVICULAR (SCAPHOID)

This brings to mind injury to the mediotarsal, commonly phrased "mid-tarsal" joint. This is serious, even though "merely a sprain." A sprained mid-tarsal joint can prove to be one of the most crippling injuries in the foot. It usually requires three to six months to rehabilitate the injured mid-tarsal region. Adequate support of the longitudinal arch is essential for many months.

Varus displacement of the forefoot with broken scaphoid driven medially may occur and it seems to be a too little-known entity. The mechanism is that of varus strain, by which the astragalus smashes the scaphoid and moves outward; the foot is inverted and rotated in about the vertical axis. (Fig. 2.)

This is a very serious accident often misinterpreted and called simply a scaphoid fracture. The position of the foot must be restored. The scaphoid fragments must be moulded into place. Uncommonly open operation is necessary to obtain a good result.

The ordinary "cracked scaphoid" is without displacement and if put at rest for six weeks generally results well.

CUBOID

This bone is usually injured by a crushing injury or by a rotary twist to mid-tarsal joint; seldom is there displacement of fragments.

Fig. 2. Varus displacement of forefoot with broken scaphoid.

A plaster boot to be worn four to six weeks, followed by leather or felt arch support, and corrective exercises, is the treatment indicated.

TALUS OR ASTRAGALUS

Fractures of the astragalus are indeed major injuries.

A common type is one having a crack running from the neck down through the body back and down the os calcis. This may mean a block of astragalus torn loose and usually displaced backward or outward. Since the subastragaloid joint accounts for most of the lateral motion of the ankle, it is important that any gross displacement of astragaloid parts be corrected to proper alignment and that weight bearing be withheld for many weeks in the more severe injuries. In certain rotary or twisting types of trauma, displacement of the astragalus may require open operation.

Prompt replacement is essential to prevent skin *slough* and subsequent *sepsis!* This applies to most of the fractures of the body.

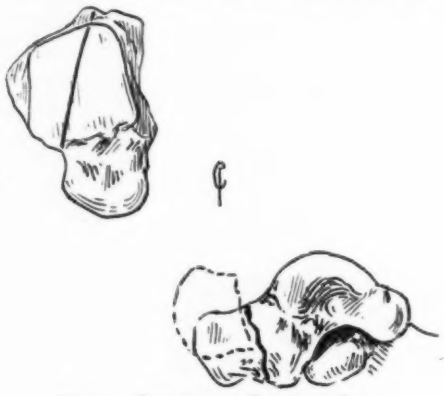

Fig. 3. Fracture of astragalus.

An attempt should be made to save this bone, even if severely smashed and compounded, since its loss leaves a foot not much good. There has been some tendency to remove compounded astragali with results that we believe are unnecessarily bad —much worse than in those cases where we have seen the bone left in.

The fracture through the neck itself, breaking off the head and displacing it upward, may sometimes be manipulated back into position. At other times it must be operated upon.

Quite frequently one observes a periosteal tear, usually small, from the side or front of the astragalus accompanying a sprained ankle. This may or may not be termed a fracture, but if it is so called, this injury must be considered the most common of the astragalus fractures.

Since the astragalus supports the tibia, and fits in the joint mortise formed by the malleoli, even the slightest displacement of astragalus must be *corrected* and *maintained* in perfect position. Forced eversion or inversion of the foot causes the upper squarish part of the astragalus to pry apart the joint mortice and usually spreads this mortice to a greater or lesser degree. There is a widening of space between the astragalus and the medial malleolus, with loss of proper weight bearing lines, even in certain sprained ankles. It is worth noting that the weight bearing line is thrown outward with even a very slight lateral displacement of the astragalus and some degree of spastic flat foot is bound to

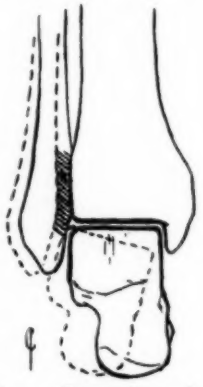

Fig. 4. Spreading of joint mortice.

result from this valgus position. *Avoid it!*

To make clearer this weight bearing line: a line dropped through the midpoint of tibia in an antero-posterior film should also drop through the mid point of the astragalus, superior surface. Again, the slightest lateral or outward displacement of astragalus in valgus is far more harmful to function than the same degree of displacement in varus because it results in spastic flat foot strain, one of the saddest clinical end-results.

A properly applied plaster boot, with foot dorsiflexed and neutral as to eversion or inversion, should have manual pressure applied beneath the external malleolus, and well padded counter pressure above the internal malleolus as the cast hardens, forcing and maintaining the astragalus into near contact with the medial malleolus. This position allows proper healing of the joint capsule and tibio-fibular ligaments maintaining that all important weight bearing line.

Adequate realignment of parts—by manipulation or if necessary by open operation-moulded plaster boot, and prolonged protection give fairly good results. Such a plaster boot moulded under the longitudinal arch should be kept on for four to six weeks followed by a leather or felt inner sole for partial weight bearing for the next four weeks.

FRACTURES OF THE OS CALCIS

The most common type you will meet is the laterally mushed and crumpled variety, accompanied by compression fracture of the spine in not a few instances.

The next most ordinary fracture of os calcis is the avulsion type: the Achilles tendon insertion holds, tearing out a chunk of bone, often triangular in shape. This may be replaced by open operation, but such a procedure tends to produce a badly humped up area of bone at the fracture edges. We have had better results in a small series of such accidents by removing most of the fragment of bone and tacking down the tendon by sutures. The foot should then be put up in partial plantar flexion for three weeks' time. Any period longer than three weeks may result in contracture of Achilles tendon and resulting equinus. Plantar flexion is a dangerous position for any kind of ankle or foot lesion and must be used guardedly.

Since we are dealing with the commoner types of fractures—here those of the os calcis—let us go on to the situation usually met.

A person falls from a ladder or veranda—usually a distance of six to ten feet, sometimes much higher—landing on the feet. The upward thrust of solid ground or cement crushes the heel bone into mushy substance, spreading it out medially and laterally, mostly laterally. The normal depression beneath the external malleolus disappears, in part if not entirely. And this occurs before swelling contributes its share of obliteration of normally depressed area. This observation, together with the history of a fall landing on the feet, may make the diagnosis simple. Any complaint of backache in the region of the twelfth dorsal or first or second lumbar vertebra should be cause for films to be taken of this region for compression fracture.

Usually such lesions show swelling of the heel fairly promptly and are not seen in time to do immediate reduction. If the patient is presented before the foot swells, and the condition of the skin is good, then an immediate reduction may be done. This procedure is not usually practicable. Pillow and sides splints, or pressure dressing with elevation of the part for three or four days is good treatment. Skin preparation of the whole foot for a day or two makes the foot ready for operative manipulation.

After aspetic draping a Kirschner wire may be put through the os calcis, from the inside outward, to prevent the wire carroming off the straight line with puncture of the plantar vessel which may cause aneurysm. The writer has seen only one such accident but the result was bad. Or, through a small skin incision on either side of the heel, tongs may be inserted to provide grip for the manual traction and remodelling to follow. In either case, whether wire or tongs are used, they come out before the operation is over. Prolonged traction gets you nowhere as compared to a strong hard pull downward and backward over the edge of the table. One of the operator's feet had best be placed against the table for sufficient pull to accomplish reduction. During the reduction the foot must be held in plantar flexion; otherwise the pull is wasted on the tendo-Achilles.

A sand bag placed under the draping is now used on which to place the foot resting on the sand bag below the inner malleolus. A folded towel sufficiently thick is laid just below the external malleolus. With impacting blows from a heavy mallet, the os calcis may be moulded so as to reproduce the normal depression below the external malleolus into which the finger may sink to normal distance.

In other words, the external malleolus again becomes normally prominent. And the lateral bulging of bone, usually greater than that on the inner side, is corrected as both sides more nearly approximate one another. Keeping the heel off the table, the wire or tongs is removed, sterile dressings, sheet wadding and plaster boot applied. Pressure manually applied *below* the malleoli as the cast hardens, helps to pre-

vent any possible displacement of the bone and tends to limit excessive callus growth.

After six to eight weeks in plaster, a shoe attachment with thumbscrew pressing an inverted half-moon shaped pad below the external malleolus, is applied. This pressure, worn as snugly as is comfortable, will prevent the heaping of bone which tends to occur in this commonest type of os calcis fracture. Raising the inner side of the heel three-sixteenth of an inch is desirable. Lateral motion is satisfactory by this method in the majority of cases.

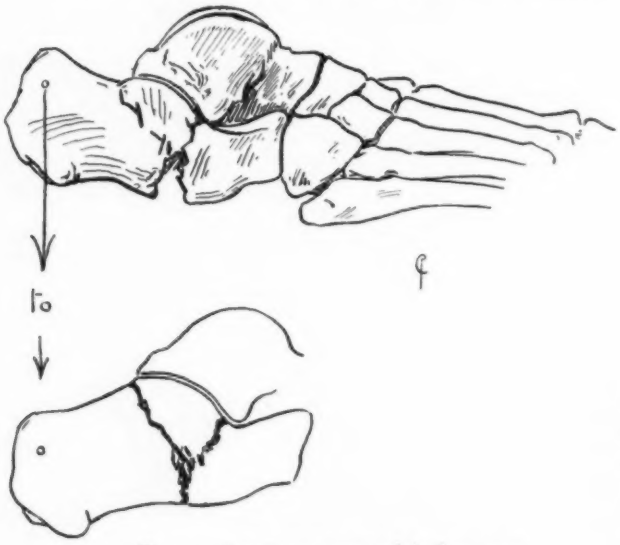

Fig. 5. A common os calcis fracture.

The technique described was worked out and developed at the Boston City Hospital by the writer's associate, F. J. Cotton. An equally excellent procedure is that of Otto Hermann. By this method, moulding by mallet and Forrester clamp precedes the downward and backward manual traction through use of tongs correcting the deformity present. Pressure pads beneath the malleoli and under the plaster, several changes of the cast and meticulous follow-up, has resulted in an excellent series of end-results in Hermann's hands.

Fig. 6. Os calcis with chunk out.

By either method a painless foot and lateral motion sufficient to accommodate the owner on rough cobblestones or uneven ground, has been accomplished as a rule. However, the surgeon may not feel any apology for the end-result if the patient can walk comfortably on a smooth floor, and yet be unable to travel with comfort over rough country.

The author wishes to express his appreciation with thanks for the drawings by his associate, Frederic Jay Cotton, M.D.

FRACTURES ABOUT THE ELBOW

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A STUDY of a large series of fractures about the elbow joint shows that this region is susceptible to a wide variety of fractures. It is the purpose of this paper to classify these fractures, so far as possible, into groups for which a specific type of treatment is indicated. Familiarity with the difficulties involved in each group and with the methods which give the highest percentage of good functional results places one in a position to institute immediately the proper treatment. This eliminates the hazards and disadvantages of indecision and harmful experimentation. Obviously all fractures about the elbow cannot be so conveniently catalogued, for various complications alter the conditions. However, there are certain groups in which experience has shown that such definite rules are usually applicable and that if they are followed a greater number of good results will be obtained. The more common fractures, such as supracondylar fractures in children, for which the treatment is well standardized, are omitted from this discussion.

FRACTURES OF THE HEAD OF THE RADIUS

In fractures of the head of the radius, where less than one-third of the head is involved and there is little or no displacement, conservative treatment is adequate. The elbow should be immobilized until the acute reaction has subsided (usually less than a week) with the joint in the position of greatest comfort, which is usually 90 degrees flexion and mid-pronation and supination. This immobilization is followed by physiotherapy, consisting of baking, gentle massage and gradually increasing active and passive motion.

Where more of the circumference of the head is involved, with comminuted fragments, usually associated with transverse fracture of the neck, more radical treatment is indicated, and in these cases it is necessary to resect the head and neck of the radius. In removing the head and neck, care should be taken to excise all of that portion of the radius which is proximal to the insertion of the biceps. The resection should not be subperiosteal, but includes the periosteum, as torn fragments of periosteum with attached spicules of bone frequently produce sufficient new bone to block motion in the joint. A flap of soft tissue is sutured over the remaining end of the radius. When this procedure is carried out early, good results are the rule, and it is therefore unwise to postpone resection of the head in cases where it is indicated. During the period of delay the process of bone repair and regeneration has begun. When this has once been instituted it is almost impossible to remove all of the new bone-forming tissue, and, even with the most careful toilet of the operative wound, recurrence of callus formation is frequently sufficient to impair the future function of the joint.

FRACTURES OF THE OLECRANON

In simple fractures of the olecranon with separation of fragments, the ideal method of treatment is one which accurately restores the relation of the fragments and provides sufficient fixation to permit early resumption of motion. The older methods of immobilizing these fractures in full extension until union occurred has proved unsatisfactory because of the difficulty of restoring motion in the joint.

Many types of internal fixation have been employed to obviate this complication. The method which has been found to be the simplest of application and the most universally satisfactory as regards functional results, is wiring the fragments with malleable, rustless steel wire. The fracture site and the fragments of the olecranon are exposed. A malleable, rustless steel wire suture is passed through the insertion of the triceps tendon just proximal to the tip of the olecranon process and through a drill hole in the shaft of the ulna distal to the point of fracture. In some instances the loop may be replaced by a figure-of-eight wire suture. The suture then crosses over the fracture site and may prevent a tendency to posterior displacement of the distal portion of the proximal fragment. The wire suture is tightened under direct vision until the fracture surfaces are accurately approximated. All small detached fragments of bone should be removed, as they predispose to the formation of excess callus and traumatic arthritis. By this method sufficient fixation is provided to assure early union with the minimum of reaction in the articular surface of the joint. Resumption of gradually increasing active and passive motion is permitted as soon as the operative wound has healed.

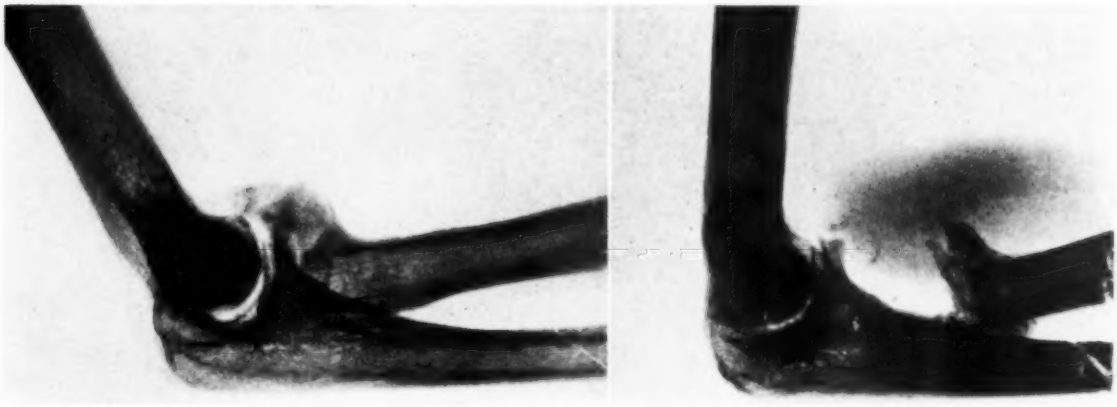
A B

Fig. 1. A, comminuted fracture of the head of the radius. B, anteroposterior and lateral views showing satisfactory resection of the head at the proper level without recurrence of new bone formation.

Degenerative changes in the articular cartilage with permanent limitation of motion may follow any fracture involving the articular surfaces of the elbow joint. These articular changes are due primarily to the actual trauma to the joint surfaces at the time of fracture and secondarily to the period of immobilization necessary to secure union. When the wire loop method is employed, the patient usually has about half the normal range of flexion and extension at the end of six to eight weeks. The rapidity with which this motion increases, as well as the amount of permanent limitation of motion, if any, depends upon the severity of the resulting traumatic arthritis. If no traumatic arthritis develops, normal range of motion is the rule. Pronation and supination are seldom diminished to any appreciable extent even in those

instances where flexion and extension are limited.

In compound fractures of the olecranon head, but repair of the ligament is difficult and usually unsatisfactory. The best method of reconstruction is to pass a loop



A B

Fig. 2. A, old comminuted fracture of the head of the radius with excessive callus production. B, same after resection, showing reformation of callus and synostosis between the radius and ulna limiting function in the joint.

and in very old patients good functional results may be obtained without surgery. The arm is dressed with the elbow flexed at a right angle, while the displacement between the fragments is disregarded. Early passive motion is instituted as soon as the wound has healed sufficiently so that one can be certain there is no active infection. The space between the fragments fills in with scar tissue and a fibrous union is formed. The range of motion in such cases is surprisingly good, frequently approximating the normal.

FRACTURES OF THE UPPER END OF THE ULNA WITH DISLOCATION OF THE HEAD OF THE RADIUS

In these fractures the maintenance of reduction presents a difficult problem. Since the annular ligament is ruptured at the time of dislocation, there is no ligamentous support to maintain the reduction after the head of the radius is reduced. Fractures in the upper portion of the ulna are prone to angulate, and if there is ulnar shortening, due either to overlapping of the fragments or to angulation, redislocation of the head will occur.

Reconstruction of the annular ligament aids in maintaining reduction of the radial of fascia lata around the neck of the radius and anchor it to the ulna through a drill hole. Fascia lata is preferable although heavy braided silk may be used. The associated fracture of the ulna may be treated by closed or open reduction, depending on the circumstances, with postoperative immobilization adequate to prevent ulnar shortening.

FRACTURES OF THE HUMERAL CONDYLES IN CHILDREN

The outstanding example of determining the proper method of treatment at the time of the acute fracture from a study of the end results is seen in fractures of the humeral condyles in children. The impression gained from the roentgenogram taken at the time of the acute fracture is misleading, since the fragment does not appear to be large, and in many instances the displacement is not great. It would appear that simple replacement of the fragment by closed reduction could easily be accomplished, with the expectation that union would occur and a good functional result be secured, as in any other type of fracture. That such assumptions are not justified has been clearly demonstrated by a study of end results of some 120 fractures of the

humeral condyles in children before ossification of the epiphyses at the lower end of the humerus.

A

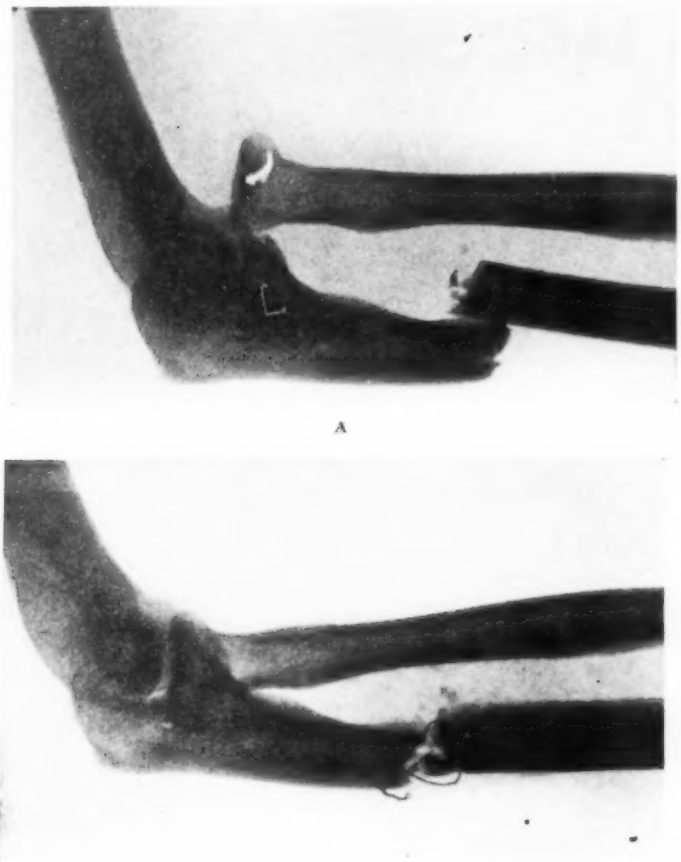
B

FIG. 3. A, typical fracture of the olecranon process with separation of the fragments. B, same after reduction, showing union with normal position of the fragments; excellent functional result.

Only fractures of the internal and external condyle are included, the detached fragment carrying with it the trochlear or capitellar portion of the articulation. Avulsions of the internal epicondyle are also included, as the problems involved in their treatment are essentially the same. They are to be clearly differentiated from the usual supracondylar fractures, so common in children, which offer an entirely different aspect, both as regards the treatment and the results obtained. The distinction between condylar fractures and supracondylar fractures of the humerus is just as vital in proper understanding of the problems involved in treatment as is the distinction between central fractures of the neck of the femur and trochanteric fractures.

If a supracondylar fracture is reasonably well reduced, union takes place with very

little, if any, limitation of function in the joint or disturbance in the future growth of the epiphysis. Experience has shown that such is not the outlook for condylar fractures. Non-union or malunion of the detached fragment is almost universal with the ordinary closed reduction, and is followed by a sequence of complications. Increasing deformity and distortion of the elbow joint occurs, due to the failure of the affected condyle to develop because of delayed or arrested epiphyseal growth. The result is a cubitus valgus or varus deformity and an unstable joint which often becomes painful after use and in later years is frequently associated with a delayed ulnar palsy. Limitation of motion is the rule in the early years following the fracture, and may persist even longer. Many patients, however, regain a full range of motion. If complications are to be avoided, immediate accurate reduction of the fracture with close coaptation of the fractured surfaces must be accomplished, as otherwise the nutrition of the fragment is impaired and destruction of the epiphysis is unavoidable.



A

B

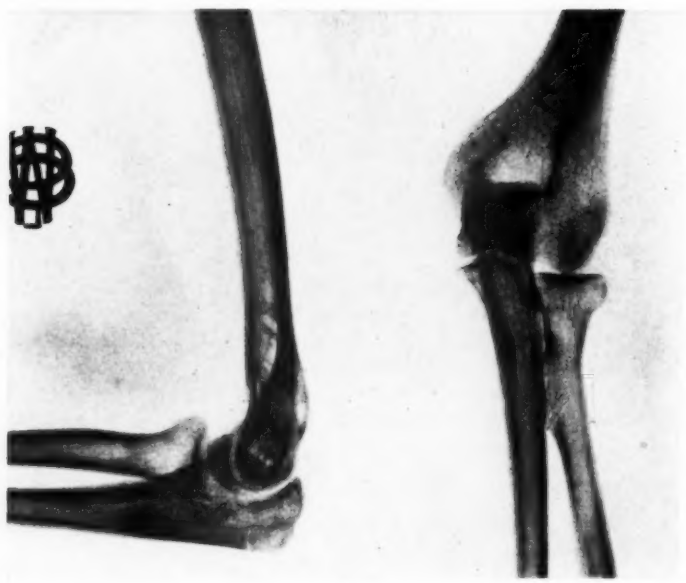
Fig. 4. A, fracture of the upper third of the ulna with dislocation of the head of the radius. B, same after open reduction of the radius and fixation of the upper end of the radius to the ulna after reduction of the dislocation.

There are certain factors connected with condylar fractures which necessitate a clear view of the fragments in securing a proper reduction, and some dependable type of internal fixation to maintain this position once it has been secured. Attached to the internal condyle and external condyle respectively, are the strong flexor and extensor group of forearm muscles. When either condyle loses its bony anchorage, the pull of these muscles displaces it,

often turning the condyle end over end and rotating it, if the fracturing force is strong enough to carry the forearm into extreme abduction or adduction. In such cases it is impossible to replace the fragment in its proper position by any type of closed manipulation. Success depends upon a clear view of the entire articular surface of the humerus and free access to the fragment, which must be turned and maneuvered about, and fixed into its proper position like a portion of a jig-saw puzzle. The pull of the attached muscles often makes this difficult even under direct vision. When the reduction is obtained, its insecurity and the ease with which the fragment is displaced can be demonstrated by putting the attached muscles under

A

B



C

FIG. 5. A, anteroposterior and lateral views. Fracture of the internal condyle of the humerus showing displacement and rotation of the fragments. B, same after open reduction and internal fixation with wire nail. C, same, six years after reduction showing solid union and normal growth and development of the elbow.

tension by slight movement of the forearm. The least pull displaces the fragment. A study of the subsequent results in these fractures has shown that even minor displacements of the condyles are incompatible with satisfactory function, malunion, non-union and growth disturbances impairing the future use of the joint. It is necessary, then, if proper union is to be obtained, to use some type of dependable internal fixation which will not allow the fragment to slip and which will hold the fractured surfaces in close apposition.

A B

Fig. 6. A, fracture of the external condyle of the humerus, partially united in malposition, treated by delayed open reduction and internal fixation. B, same, three years later showing degenerative changes in the condyle and beginning deformity in the joint.

Many types of internal fixation have been tried, including absorbable sutures, steel wire, bone screws, etc., but it has been found that the simplest and most reliable is the ordinary wire nail. It fulfills all the requirements for fixation, is easily inserted, apparently does not materially damage the epiphyseal area, and can be easily removed under local anesthesia at the end of a few weeks, when union is solid enough to maintain position.

It is necessary in many cases to drive the nail through the epiphyseal growth line. The theoretical objection cannot be denied that it is undesirable to leave a foreign body through the epiphysis for so long a time; practically, however, no irregularity in growth or premature ossification of the epiphysis has been observed following the use of the nail. Certainly, as far as the future fate of the epiphysis is concerned, the advantages attained by prompt and accurate union of the condyle greatly outweigh any damage that the nail may do.

Incomplete fractures of the condyles without displacement have uniformly shown perfect anatomic and functional results when treated by the closed method. We may accordingly conclude that it is not the dissolution of bone continuity, but failure to secure accurate reduction and maintain this reduction, which produces the epiphyseal changes seen in similar fractures with displacement of the fragments. Further reasoning would indicate that, if we were able to replace accurately and hold in position the displaced fragments immediately after injury, we could expect to obtain the same satisfactory end results.

Comparison of the end results obtained in the treatment of displaced fractures of the humeral condyles in children by the open and closed methods has conclusively shown that both the anatomic and the functional results are far superior in those

cases treated by the open method. All such cases are now routinely treated at the time of injury by open reduction and internal fixation by means of a wire nail.

A B

FIG. 7. A, "T" fracture of the lower end of the humerus with separation of the fragments. B, same, after open reduction and internal fixation with bone nail.

In complete fractures of the humeral condyles treated by delayed open reduction the results have been disappointing. It was hoped that accurate reposition of the displaced condyle, even after several months, would be followed by firm union without serious epiphyseal disturbance. The follow-up study of this group, however, showed that although bony union was assured, disturbance in epiphyseal growth with subsequent deformity of the joint occurred in practically all cases. Certain technical difficulties encountered at operation probably account in a large measure for the disappointing results.

In order to expose and mobilize the detached fragment sufficiently to derotate it, or to maneuver it back into its original position, practically all of the soft tissue attachments have to be severed. In some cases the fragment is unavoidably detached completely. Efforts to avoid disturbance of the blood supply by decreased exposure and mobilization result in poor reduction and insecure fixation, which are equally bad. Epiphyseal disturbance is to be expected in those condyles completely detached at operation, but it is disappointing to observe similar changes when a relatively large amount of the muscular attachment is preserved.

In view of the poor results obtained in delayed open reduction, it is evident that in the presence of an acute fracture, valuable time should not be lost in conservative efforts at closed manipulation. The definite opinion that open reduction is necessary should lead to immediate intervention.

Avulsion of the internal epicondyle is in reality an epiphyseal separation, resulting from tension produced by the flexor group of muscles. From the standpoint of treatment, it is anatomically and physiologically comparable to fractures of the humeral condyles. In order to obtain union and prevent arrest of growth in the epicondyle, the separated epiphyseal surfaces must be placed in close coaptation and held until union occurs. Complications are frequent in the untreated cases. Limitation of extension of the elbow is frequently seen, due to blocking of the olecranon

which fits in closely against the internal epicondyle when the elbow is extended. Pain after use and bony tenderness about the epicondyle persist indefinitely in some cases. Delayed ulnar palsy frequently results from adhesions about the nerve and deformity in the ulnar groove.

Proper maintenance of position of the detached epicondyle can only be secured by open reduction and dependable internal fixation. The use of absorbable and non-absorbable sutures has proved inadequate, as they do not provide sufficient fixation to prevent recurrence of the deformity. Nailing the epicondyle in position with a small wire finishing nail has proved to be the most satisfactory method of fixation.

In fractures of the humeral condyles in adults, while the problems of growth disturbance seen in children do not arise, it is desirable to restore as accurately as possible the normal anatomic architecture of the joint. Open reduction, using the type of internal fixation that seems adequate, is necessary in cases where satisfactory reposition cannot be obtained by closed reduction.

A B

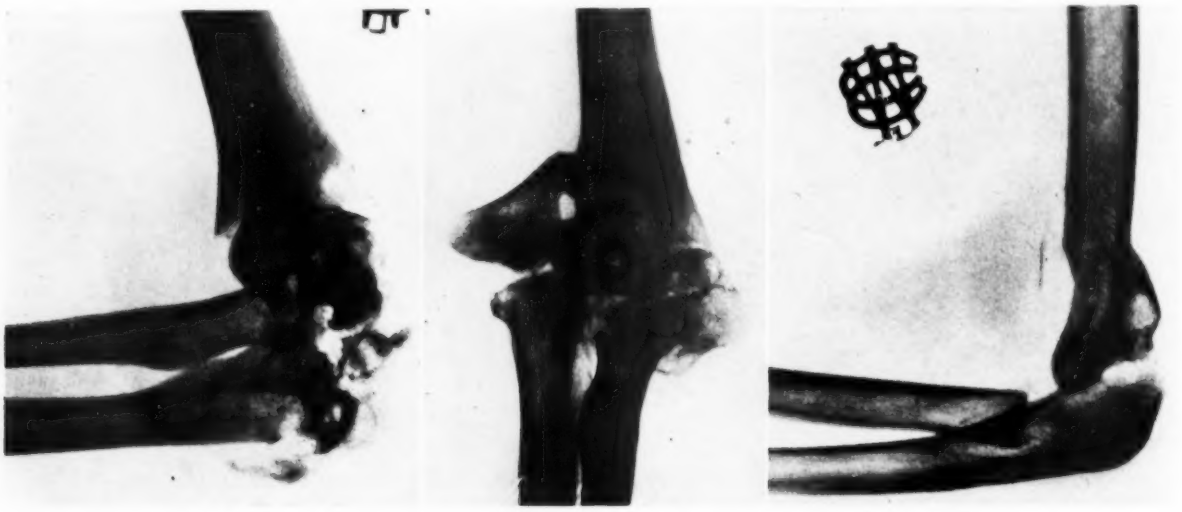
Fig. 8. A, compound comminuted fracture of the elbow with gross displacement of the fragments. Inverted V-shaped deformity of the humeral articular surface characteristic of "T" fractures is clearly shown. B, anteroposterior and lateral views after conservative treatment. Displacement of the fragments still present but satisfactory functional range of motion.

"T" FRACTURES INVOLVING THE LOWER END OF THE HUMERUS

In the adult the most common type of fracture involving the lower end of the humerus is the "T" fracture, in which the fracture line starts in the groove on the articular surface of the trochlea and extends upward between the condyles for varying distances and then transversely across the shaft, separating the condyles from each other and from the shaft itself. The muscle tension exerted on the outer edges of the condylar fragments pulls them downward, tilting the central portion of the articular surface upward and resulting in an inverted V-shaped deformity, which materially interferes with motion in the joint. Usually these fractures result from considerable violence and are frequently associated with compound wounds. They may also be associated with severely

comminuted fractures of the olecranon and upper end of the radius.

In the simpler type of fracture, where the fragments are not comminuted and compound wounds are not present, open reduction with some type of internal fixation, preferably nailing with metal or bone nails, gives satisfactory results. Closed reduction is usually associated with tilting and rotation of the fragments, resulting in narrowing of the humeral articular surface due to the V-shaped deformity described above. Full extension of the joint is prevented by inability of the olecranon to fit properly into the narrowed articular surface. A permanent limitation in extension of 30 to 40 degrees less than normal is the average result.



A B C

Fig. 9. A, extensive compound comminuted fracture involving all the structures of the elbow joint. B, after union without infection. C, after arthroplasty and re-establishment of satisfactory range of motion.

In the more severe injuries, with comminution and complicating fractures of the ulna or radius, no type of closed manipulation or open reduction will restore the normal alignment of the fragments. The type of treatment which has yielded the best results with the least risk to the patient is some type of traction and suspension with the institution of early motion. A method of treatment in favor in England at the present time is simply to suspend these fractures with a cuff and sling about the neck with the elbow in a position of flexion about 10 degrees beyond a right angle. No bandages or splints are used, and instead the alignment of the fragments is secured by gravity traction from the weight of the arm. Early motion is instituted. It is stated that, although there is considerable derangement in the anatomic architecture of the joint, fair functional results are obtained.

EXTENSIVE COMMINUTED FRACTURES OF THE ELBOW JOINT (SIDE-SWIPE FRACTURES)

This is the most serious injury encountered about the elbow joint. All varieties and variations in the extent of the fracture may be seen, from simple comminution of the upper portion of the shaft of the ulna and olecranon process to extensive compound injuries involving all the structures composing the elbow joint and often associated with fractures of the shaft of the humerus. In the more severe injuries the damage is so extensive that one cannot expect to restore, even approximately, the normal anatomic relationships between the fragments; hence, efforts at reduction either by the open or closed method are usually inadvisable. The general alignment of the fragments may be improved by gentle manipulation and moulding. This is fol-

lowed by conservative methods of suspension and traction which can conveniently be accomplished by a metal frame extending out from the side of the bed with a Thomas ring against the chest wall and an upright or overhead pulley to suspend the forearm in an upright position. Such an arrangement permits traction on the elbow in a direct line with the shaft of the humerus by means of a broad cuff around the flexed forearm and direct upward traction on the forearm by a second system of pulleys attached to the upright or overhead frame on the bed. Such continuous traction maintains the relative position of the fragments and allows early active and passive movement in the elbow joint.

When the fracture is associated with lacerated or compound wounds, which is frequently the case, the same principles involved in the treatment of compound fractures elsewhere are employed. If the fracture is seen within the first six or eight hours, conservative débridement of the skin edges and loose closure of the wound should be attempted. Extensive surgery in attempting to replace the fragments or to hold them in position by various types of internal fixation is to be avoided, as the added trauma and further exposure of the fracture will tend to spread and increase infection. If the fractures are seen late, only the grossly contaminated and devitalized tissues are removed and the wound is left open.

The results obtained by following the general plan of treatment outlined above have proved surprisingly satisfactory. Gross infection has been avoided in the majority of compound fractures and in most of the cases a useful range of motion of from 40 to 90 degrees has been secured.

In forty cases treated by the above outlined method, there were thirty compound fractures. In this number active infection occurred in six, and in these there was marked limitation of motion or complete ankylosis. Of the thirty-four remaining cases, which were not compound or in which gross infection did not develop, ankylosis was rarely seen. The range of motion varied from 10 degrees to practically normal, with an average range of about 50 degrees.

In the severely compound comminuted fractures, further complicated by infection, ankylosis is to be anticipated. In such cases the forearm and elbow should be placed in the optimal functional position. Where there has been no active infection, conservative efforts should be made to maintain as nearly as possible the relative alignment of the fragments as an aid to future reconstructive work. Restoration of a movable joint by means of an arthroplasty has been successfully employed in a number of these cases, but arthroplasty should not be attempted where there has been gross infection or where the approximate contour of the joint has not been maintained. When the head of the radius has been crushed or remains dislocated it may be resected at a suitable time later with the expectation of increased joint movement.

In the less extensive injuries, not associated with compound wounds, more aggressive measures to secure reduction and maintain the position of the fragments can safely be undertaken. Comminuted fractures of the upper end of the ulna, with fracture of the olecranon, may be wired together, permitting early movement of the joint without displacement of the fragment. Such injuries are frequently complicated by crushing fractures or dislocations of the head of the radius. When the head of the radius is crushed it should be resected at the time the fracture of the ulna is repaired, as otherwise the usual limitation of motion, both in flexion and extension, and in pronation and supination, seen in ordinary fractures of the head of the radius, will result.

Dislocation of the head of the radius should be reduced by manipulation. If this is impossible, or if the dislocation recurs, it is better left alone until the fracture of the ulna has united, when it may be resected. Attempts at operative reduction with fixation to the ulna or reconstruction of the

annular ligament to maintain its position involve too much additional trauma associated with the other injuries. In addition, experience has shown that in such injuries it is not always best to restore too closely the articular components of the elbow joint, as better function may be obtained if motion in the joint is simplified and more space provided by resection of the head of the radius.

CONCLUSION

In conclusion it may be stated that in dealing with fractures about the elbow joint, the nearer the normal anatomic architecture of the joint is restored, the better the functional result will be. Open reduction with the use of internal fixation is necessary in many cases to secure the proper reduction of the fragments and to maintain them in position until union has occurred. It must be remembered, however, that in doing open reductions a simple fracture has been converted into a compound fracture and all the results and disadvantages so well recognized in performing open reductions elsewhere must be carefully weighed and taken into consideration. Infection following open reduction usually results in failure to accomplish the purpose of the operation and adds a complication which increases in most instances the damage which would have resulted from the original fracture. Conservative treatment, particularly in the badly comminuted fractures, will usually give better functional results than ill-advised efforts at open reduction.

"In addition to the rather acute bone atrophy, incident to treatment or immobilization after a fracture, there is a chronic bone atrophy that is always present in limbs which are extensively paralyzed and which as a result of the paralysis have not been used for weight bearing."

THE EMERGENCY CARE OF CRANIOCEREBRAL INJURIES*

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SWIFT[1] has stated that 112,000 craniocerebral injuries occurred in the United States in 1932. Since then, with the increasing use of the automobile, the yearly incidence must have risen even higher. All of these injuries are surgical emergencies, and as such they may require immediate treatment regardless of hospitalization or lack of it, by any member of the medical profession regardless of his specialized knowledge or absence of it. Such emergency therapy, if properly carried out, will save a few lives at the start, and, which is more important, make it possible to treat the patient more efficiently and therefore with a lower mortality and morbidity later on, after the emergency period is past. If, in addition, certain fundamental principles are followed in taking the history and making the examination when the patient is first seen, much time may be saved, many unnecessary procedures may be eliminated, and the patient may be assured adequate early operative relief when and if that is essential.

There are three questions that must be answered by any physician who undertakes or is forced to treat an acute craniocerebral or "head" injury. These are: (1) Is the patient in surgical shock? (2) Is the injury one that will require treatment by operation within the next forty-eight hours, and, if so, is the hospital in which he is being examined adequately equipped to handle such a procedure? (3) What is the intracranial or cerebrospinal fluid pressure as measured on a manometer and by means of a lumbar puncture?

As a preliminary to any investigation, the injured individual should be brought under cover as soon as possible. It is only in this way that he can be saved the dehydration that comes from lying in the sun and the exhaustion and depletion of his circulatory reserves which follow exposure to wet and cold. It makes no particular difference at this time what sort of shelter it is, providing, of course, that it is tight and warm or cool as the weather demands. If an ambulance, or any smooth-riding substitute for an ambulance, with room enough to permit the victim to lie flat, is available, this shelter should be the nearest hospital. A twenty minute or half-hour ride at this time and under such conditions will add little if any risk and the resulting increased efficiency in the future care more than makes up for this addition.

With the patient indoors, the attending physician's first responsibility is to see to it that no attempts are made to take the patient's clothes off. This must not be done until the absence of surgical shock has been verified. The extensive manipulation, the exposure and above all the wasted time are all or each of them adequate reasons for this prohibition. Having settled that, the doctor is in a position to find out the answer to the first of the three questions propounded, as to the presence of surgical shock. The answer is of the utmost importance, since if there is surgical shock, any further examination, transportation or treatment is absolutely contraindicated until such time as the patient has recovered from this condition. The only exception to this statement is that intravenous medication with 50 per cent glucose or sucrose solution, or a blood transfusion may be given. The simplest and most reliable way to determine the presence of shock is to measure the patient's blood-pressure. To

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do this, the arm can be exposed by slitting the coat and shirt sleeves up their seams with a pen-knife. Cut in this way, the sleeves may be repaired later without permanent damage to the garment and the patient be saved the manipulation that is otherwise required to remove the coat. Both systolic and diastolic pressures must be measured. If the difference between these two figures (in other words, the pulse pressure) is below 15, it may be taken for granted that the patient is in shock. If it is 20 or above, a second observation should be made at the end of thirty minutes; if, at that time, the systolic pressure has fallen or the pulse pressure is decreased, the diagnosis of surgical shock is again justified. Should the systolic pressure remain the same, however, or the pulse pressure be increased, there is no shock. In case no change has occurred, a third reading should be made at the end of another half hour. It may be helpful to count the pulse also, although the rate is not an absolutely reliable indicator in this type of injury.

When an adult patient is in shock, an attempt should be made to give him 100 c.c. of 50 per cent glucose intravenously or to transfuse him with 250 c.c. of citrated properly matched blood. The circumstances will determine which, if either, of these procedures is possible. In craniocerebral injuries *do not give morphine*. Its depressant effect on the respiration may serve to kill a patient who would otherwise recover. Fluids by mouth may be permitted, but the patient's head should *not* be raised. Care should be taken that he is warmed but not over-heated. In particular, he must not be moved or questioned, and he should be protected from police, insurance adjusters and anxious relatives. If and when he recovers from his shock or if he has not been in shock, as determined by the blood pressure measurements, the doctor may take steps to consider the second of the three questions.

The answer to the second question will determine whether or not the patient's injury is one that requires operative treatment within the next forty-eight hours. There are two, and only two, craniocerebral injuries which require such therapy. They are an *extradural hemorrhage* and *a compounded fracture of the skull*. Of the two the extradural hemorrhage is the more acute emergency, and operation at the earliest possible moment after the surgical shock has abated may be imperative. The diagnosis must be made, therefore, even earlier. The preliminary steps toward this end are to be taken while the patient is recovering from the shock. The first of these is to get an accurate history, but this does not mean placing the blame for, or determining the mechanism of the accident that produced the damage. It *is* concerned, however, with the problem of whether or not the patient's present consciousness was preceded by a period of unconsciousness, or whether or not his present unconsciousness was preceded by both unconsciousness and consciousness in that order. This will require a lawyer-like cross examination of all available witnesses and, if possible, of the patient himself. Unverified statements should be accepted only at their face value and for want of something better. Attempts should always be made to check the accuracy of the witness's observation by asking questions about extraneous details that can be verified by known physical facts. Such questions might include the number of people in the automobiles that might have been involved in the accident, the presence or absence of police, the number and sex of the rescuers, the time of day, the state of the weather and so forth. When all available historical data have been obtained, it should be possible, in most cases, to say definitely whether or not the injured person had been knocked unconscious at the time of the accident and if so whether or not his unconsciousness had persisted.

A brief examination of the patient is now necessary. This is done to determine the presence of a hemiplegia or hemiparesis, aphasia, facial palsy, the difference between the knee and ankle jerks on the two ex-

tremities, the presence or absence of Babinski reflexes or dorsiflexion of the great toes, the pulse rate, the rate and rhythm of the respirations, a rough estimate of the number, type and severity of associated injuries and finally the presence or absence of a wound of the scalp. With the history and the results of this examination, it should be possible at this time to class the patient as having either a suspected extradural hematoma or as suffering from a non-operable intracranial injury as far as this particular problem is concerned.

If it can be shown that he has or is suspected of having an extradural hematoma, steps must be taken to provide at least one, and better two, suitably matched donors. Furthermore, he must be moved *at once* to a hospital equipped with, among other things, an efficient suction apparatus, a silver clip outfit, a Hudson drill with three burrs, rongeurs, bone-wax, small curved needles, a supply of #7 or similar silk, ventricular and matched lumbar puncture needles and manometers, provisions for doing an emergency blood transfusion and facilities for the taking of portable *x*-ray films, in addition to an adequate supply of hemostats and so forth. The surgeon retained to treat the injured man should not be asked or expected to assume the responsibility for doing this dangerous and difficult operation in any hospital not equipped with these minimum requirements. If they are not available, the community which supports such a hospital should be informed of it in order that they have the opportunity to correct the deficiency or to see to it that the hospital is known as one that is not able to deal with these surgical emergencies and that will not, therefore, admit them to its beds.

After transfer to the proper hospital, one flat *x*-ray film of the side of the skull beneath which the hematoma is suspected of being located should be taken at once. This film must visualize the groove of the middle meningeal artery and its branches, the shadow of the lateral sinus and also the fracture line if one is present. If, in an extradural hematoma suspect, this fracture line can be shown to cross either the artery or the sinus, the diagnosis is sufficiently confirmed to warrant a transtemporal exploration of the suspected side without further evidence. If the diagnosis still remains in doubt, a lumbar puncture should be done, the intracranial pressure measured, a specimen of cerebrospinal fluid obtained and its red blood cell count determined. If the suspected presence of an extradural clot cannot be confirmed at this time and operation is decided against for that reason, the case passes out of the emergency category. The further measures necessary for more accurate diagnosis and future treatment, as well as a discussion of the operative technique, do not come within the scope of this paper.

If, as the result of the history and examination described above, it is determined that the patient is not an extradural hematoma suspect, one-half of the doctor's second question has been answered in the negative. To answer the other half, namely, the possibility of a compounded fracture of the skull, is even more simple. The examination described above has determined whether or not there is a wound of the scalp. If there is not, the answer to this second half is obviously "*no.*" If there is, it may be either yes or no, and the only sure way to settle the problem is for the examiner to insert his sterilized finger into the wound and ascertain whether or not a fracture line is palpable. If it is palpable but can be felt to be covered by intact periosteum, the answer is still *no*, and the local injury may be regarded as nothing more than a lacerated wound of the scalp.

On the other hand, if the fracture line is palpable as uncovered rough edges, the answer is *yes* and the first steps toward débridement and suture must be taken at once. These steps[2] consist largely in knowing what not to do. First among them is to refrain from attempting to clean the wound, shave the head, remove spicules of bone or do anything except tie large bleeding arteries in the wound itself. The second

prohibited activity is irrigation of the wound. This is particularly dangerous because any irrigating fluid introduced into the wound will run through the fracture into the meningeal spaces and introduce bacteria that would not otherwise contaminate this region, thus causing meningitis. The only positive action that is permissible is to cover the wound with a piece of sterile gauze and a bandage to hold the dressing in place. This dressing must not be removed until after the patient has been put on the operating table preparatory to doing the major débridement. It should be emphasized here that the substitution of instruments, lights or other things for the examiner's finger will not prove satisfactory and the percentage of errors in diagnosis will rise in direct proportion to their use.

Whether or not the patient has a scalp wound or a compounded fracture of the skull, he should now be examined for associated injuries, voluntary paralyses, reflex changes, abnormal reflexes, cranial nerve palsies and the like. This examination is identical with that done in connection with making the decision as to whether or not an extradural hemorrhage is present. It may be substituted for the former or need not be done at all if it has already been carried out. Such a preliminary survey does not require the removal of any of the patient's clothes. The abdomen and chest may be adequately examined by loosening the clothes at the waist in any way that seems best. The extremities need not be bared and only the shoes and stockings have to be completely removed. With the information thus obtained, with the patient out of surgical shock and the need for emergency operative treatment of either a compounded fracture of the skull or an extradural hemorrhage settled, the associated injuries can be properly evaluated and dealt with temporarily as required.

Should the answer to the second question be "yes," the third question, "What is the intracranial pressure?" does not arise as an emergency. It becomes only a side interest in deciding, on the one hand, on the removal of an extradural clot as soon as possible, or, on the other, upon dealing by débridement with a problem in sepsis which, if mishandled, will produce meningitis or cortical abscess or both in a large percentage of cases. If the second question is answered in the negative, the need to determine exactly the degree of intracranial pressure still exists as an emergency. Before proceeding to this, however, the patient should be moved, if necessary; or if this is not necessary, he should be undressed and put to bed. The physician should be interested not only in knowing how high the cerebrospinal fluid pressure has risen, but he should be equally anxious to verify the presence of a subnormal figure. This information can be obtained only by actual measurement on a manometer with the aid of a lumbar puncture. It makes no difference whether the manometer used is of the stand-pipe or mercury variety, but it must be in working order and it should be one of the recent models.

It may not be amiss, at this point, to emphasize the fact that the lumbar puncture can be done as easily with the patient lying comfortably stretched out on his side, as it can with his chin and knees approximated, his discomfort extreme and his apprehension increased on that account. A hasty glance at any standard anatomy will satisfy the most skeptical that any significant increase in the separation of the lumbar spinous processes by flexion of the cervical spine and the thighs is an impossibility. The 2 or 3 mm. clearance necessary to introduce a lumbar puncture needle between adjoining bony prominences is available even when opisthotonos is present. The usual extreme flexion is effective only as a means of restraint in uncooperative or unanesthetized patients and never as a means of increasing the ease with which the needle can be inserted. Except in deeply comatose patients the site should be anesthetized adequately with novocaine or the like. To do this, it is essential to use first a hypodermic and then a 2-inch, small bore needle. The layers, including the

periosteum on the bony points and the epidural tissue, must all be injected one by one. The injected area has the shape of a cone, with its apex at an intradermal wheal and its base next to the dura. Only in this way can the operator and the patient be saved embarrassment and pain, with resulting haste and inefficiency, when, as frequently happens, the needle must be reinserted several times. In reading the pressure on the manometer, the lowest figure should be accepted as most nearly approximating the true level, particularly in uncooperative, restless patients. If the pressure is above 160 mm. of water or 10 mm. of mercury, enough cerebrospinal fluid should be removed, regardless of the amount, to lower the pressure to 110 or 8, according to the type of manometer that is used. If the pressure is 50 mm. of water or less, or 6 mm. of mercury or less, less than 0.5 c.c. of fluid should be removed. This is only taken to determine the approximate amount of blood that is mixed with it.

When it has been determined thus that the intracranial pressure is higher than normal, it is certain that the patient has one of three non-operable brain lesions, providing he has, in fact, been struck on the head sufficiently hard to produce any degree of unconsciousness. If the removed cerebrospinal fluid is grossly clear, he is suffering from *edema and congestion* of the brain. This is obviously no longer a surgical emergency and the future treatment by dehydration or repeated lumbar puncture or both can be carried out without further risk. If there is a moderate amount of gross blood in the removed fluid, the patient is suffering from a *contusion of the brain*, in addition to the *edema and congestion*. Again, no emergency exists any longer and future treatment by repeated lumbar punctures can be carried out at leisure. If the removed fluid is pure blood or contains a large amount of admixed blood, the patient has a *lacerated brain* complicating the *contusion, edema and congestion* (which are all also present). Despite the mortality of 41.0 per cent, even this condition is not an emergency, and the necessary daily lumbar punctures can be performed with deliberation. Two other conditions that may have an associated increased intracranial pressure are operable, but neither can be considered as requiring emergency therapy. They are the *subdural hematomas* and the *depressed fractures*.

If the intracranial pressure is found to be below normal and surgical shock has been eliminated as a factor, there is only one diagnosis that can be made—that of *toxic dehydration*. This complicates and is present in addition to any or all of the non-operable pathologic entities detailed in the preceding paragraph. It does not constitute a surgical emergency once it has been recognized, but is a common complication seen in about 3 per cent of these injuries. It is easily treated by forcing liquids, 5000 c.c. or more per twenty-four hours usually being required. The demonstration of toxic dehydration should not lead the surgeon, however, into the cardinal error of neglecting to treat the brain injury that always accompanies it and of which it is merely a complicating factor.

There is one other condition which, while not a true emergency in the sense of surgical shock or an extradural hemorrhage, nevertheless should be diagnosed and therefore treated at the earliest moment that the patient's general condition permits. This is the injury which produces *cerebrospinal rhinorrhea*. It results from the incarceration of an open out-pouching of the dura and arachnoid in a fracture of or near the cribriform plate. The diagnosis is made by finding cerebrospinal fluid draining from the nose or into the posterior nasopharynx. In the latter case the fluid may be swallowed and the diagnosis missed if the physician is not on the alert. Failure to close the fistula results inevitably in meningitis, but closure can be done only by way of a transfrontal bone-flap operation. Such a procedure, urgent though it is, is of too great a magnitude to carry out without adequate pre-operative preparation. As a result, although the necessity calls for

emergency therapy, the only effective procedure necessitates deliberation.

CONCLUSIONS

The emergency care of craniocerebral injuries requires the physician in charge to answer three questions:

1. Is the patient in surgical shock?

2. Is the injury either an extradural hemorrhage or a compounded fracture of the skull, and therefore one that will require treatment by operation within the next forty-eight hours? If so, is the hospital in which the patient is being examined adequately equipped to handle such a procedure?

3. What is the intracranial or cerebrospinal fluid pressure, as measured on a manometer and by means of a lumbar puncture, and is the patient suffering from an uncomplicated non-operable traumatic brain lesion, or has he, in addition, some degree of toxic dehydration?

The answers to these questions will determine the extent of the immediate examination of the patient, the need and safety of his transportation to another hospital, and to some degree the type of future treatment and the ultimate prognosis.

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"Minor lesions [of the spinal cord and nerve roots] may escape notice; consequently, when a patient with a fractured spine is first seen, the knee jerks, plantar reflexes, ankle jerks and abdominal reflexes should be tested."

The brief quotations in this issue are from the Second Edition of "The Management of Fractures, Dislocations and Sprains," by John Albert Key and H. Earle Conwell (Mosby).

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